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PART I. BOTANY AND FORESTRY

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PART II. ZOOLOGY

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PART I. BOTANY AND FORESTRY

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PART I. BOTANY AND FORESTRY

BOTANY

Papers of the Michigan Academy of Science, Arts, and Letters,
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TWO WINTER DIATOM COMMUNITIES OF MICHIGAN STREAMS

JOHN L. BLUM*

ALTHOUGH river algae have long since been catalogued rather thoroughly by taxonomists, relatively few studies have been made of their communal life and the conditions that determine it. Those which flourish in winter have received much less attention than those growing in summer. This paper describes briefly two winter diatom communities, one composed of *Diatoma vulgare* Bory and the other of *Gomphonema olivaceum* (Lyngb.) Kütz., which have been investigated in streams of southeastern Michigan. Unlike most diatoms, the colonies of these algae, when they grow massively, can be recognized easily in the water. They are therefore of special interest and lend themselves well to ecological study.

Most of the experimental work was done in the Saline River, but numerous observations and water analyses were made in other streams near Ann Arbor. All localities that furnished field records are in Washtenaw and Wayne counties, Michigan, and all streams mentioned are part of the St. Lawrence drainage system.

Both of the species under consideration have been described as winter dominants by European writers, including Budde (1928, 1930), Butcher (1932), Kolbe (1932), Jürgensen (1935), and Raabe (1951). None of these workers, except Butcher, have made quantitative studies of the growth of these algae; Butcher's observations are confined to counts of algae growing attached to submersed glass slides.

Butcher has described a Diatoma-Gomphonema "community" in the Tees River, England. However, the algae do not appear from his account to grow massively in the Tees. In southeastern Michigan these algae can scarcely be regarded as a single community, for they represent highly competitive units whose seasons of growth do not coincide.

* I express my sincere appreciation to the University of Michigan and to the Department of Botany for the Emma J. Cole Fellowship in Botany, which I held while the work reported here was carried out.

Filaments of *Diatoma vulgare* are attached to rocks in the stream bed by a small mass of mucilage at one end of the lowermost cell of the series. The delicate, dark-brown filaments grow abundantly on rocks or as epiphytes on Cladophora, but they are limited to the swiftly-moving water of riffles or shallows. The areas immediately downstream from relatively large rocks on the bed of these shallows are known to have slight water movement. Diatoma does not grow at all in these places, although all about such an area it thrives. The contrast is especially sharp in early fall, when the water level is low and Diatoma is growing rapidly.

In the autumn of 1952 this alga rose to dominance in unpolluted parts of the Saline River and the Huron River as soon as water temperatures had fallen below about 15° C. (Fig. 1). Throughout the early winter period the dominance of this form was uncontested on at least certain eutrophic riffles of these streams, although on other riffles it was completely absent as a macroscopic unit of the vegetation. In spite of numerous water analyses and comparisons, no cause has as yet been found for these peculiarities of distribution.

On some unpolluted riffles of the Saline River colonies of *Gomphonema olivaceum* gradually but surely took over the sites occupied by Diatoma as the winter progressed, and by February 20, 1953, they had largely replaced the Diatoma. On certain riffles in the Huron River and in various tributaries of the Huron, the Saline, the River Rouge, and the Lower River Rouge, *G. olivaceum* grew as the dominant winter alga without Diatoma as precursor. In other riffles of these streams which superficially appeared well adapted to colonization by the algae, neither of them grew macroscopically. In late February and March, growth of *G. olivaceum* was no less than luxuriant in many of the streams studied.

The colonies of *Gomphonema olivaceum* are composed of thousands of cells attached at the ends of long, branching pedicels. As the living cells grow and reproduce they secrete abundant gelatinous material. The pedicels, and eventually the colonies, become confluent and form conspicuous tan-colored, jelly-like masses, as much as one centimeter thick, on rocks in the stream bed. At their maximum development these masses cover, like a viscous skullcap, virtually every rock on the riffles.

The detachment of Diatoma in the Saline River during January and February was slow and imperceptible because of the small size

of the individual filaments. The colonies of Gomphonema, however, became torn by water currents and water-borne debris soon after they had attained maximum size; large pieces separated from the mass and were conspicuous as they floated downstream, starting about February 15. Throughout February and March normal development of the colonies was more than enough to compensate for this loss. Growth had effectively ceased by April 4, however, and by mid-April *Gomphonema olivaceum* had almost entirely disappeared from unpolluted riffles. In early April Diatoma entered upon another growth period. To judge from observations made previously, this

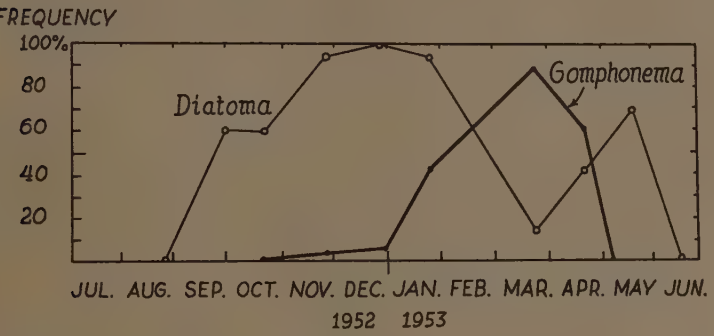

FIG. 1. Frequency of *Diatoma vulgare* and *Gomphonema olivaceum* in the Saline River (unpolluted portion) as determined by transects of the stream made at approximately monthly intervals throughout the fall and winter, 1952–53

alga reaches its secondary maximum in mid-May, and disappears shortly thereafter. In the second cycle most of the Diatoma filaments grow as epiphytes upon young Cladophora plants, which become a conspicuous part of the stream vegetation at this season.

Total development of Diatoma and Gomphonema in polluted[1] riffles of the Saline River was small as compared with total development in unpolluted riffles. The maximum growth of Diatoma in unpolluted water occurred in December, whereas its best development in polluted water was delayed until late January. Growth of Gomphonema in the Saline River followed the same pattern: in unpolluted water it attained dominance in late February and March,

[1] This pollution is both domestic and industrial in origin.

but in polluted water dominance was delayed until mid-April. On April 16, 1953, this alga showed, remarkably enough, good growth in polluted riffles at a time when it had largely disappeared from clean-water habitats. Such colonies as then remained in unpolluted riffles were largely in tatters and clearly moribund.

A study was made of the development of *Diatoma vulgare* and *Gomphonema olivaceum* upon sterilized rocks placed in unpolluted riffles of the Saline River. All rocks set in the stream between October 27, 1952, and April 1, 1953, were quickly colonized by Diatoma, often so rapidly that the new colonies were visible to the eye within ten days. Colonization by Gomphonema was equally rapid, but did not begin until about November 25. Sterilized rocks placed in the stream from November 25 through April 4 soon acquired colonies of this alga. Colonization of Gomphonema had largely ceased by April 10.

In Figure 1 are shown frequencies of these algae in an unpolluted riffle in the Saline River, as determined by monthly transect studies made by means of a graduated rope stretched across the stream. Presence (positive) and absence (negative) of the algae in alternate linear decimeters were noted. Frequencies were arrived at by ascertaining the percentage of positive decimeters in the total of recorded decimeters.

Summary

1. The growth of two winter-dominant diatoms, *Diatoma vulgare* and *Gomphonema olivaceum*, has been followed within streams of southeastern Michigan. Determinations of frequency of the algae in the Saline River were made by the transect method.

2. Diatoma is dominant in unpolluted riffles from October through January. Gomphonema replaces it, apparently as a competitor species, in mid-February and remains dominant until early April. In April and May Diatoma exhibits a second growth period in which it is again temporarily dominant.

3. Both algae are capable of colonizing new areas at any time throughout their periods of growth and dominance.

4. Growth of both diatoms in polluted riffles of the Saline River is much slower and dominance of each species is attained about four to six weeks later than in unpolluted riffles.

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GROWTH, REGENERATION, AND PRECOCIOUS ROOTING IN *RHIZOPHORA MANGLE**

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THE phenomenon of germination of seeds while still on the mother plant, generally designated *vivipary*, is well shown in some of the mangroves and has long attracted the attention of botanists, and travelers in general. In the red mangrove, *Rhizophora mangle* L., common in Puerto Rico, where the present study was conducted, the seedlings develop very long hypocotyls, which terminate in short tips (radicles) on which the tips of branch roots can often be seen before the fall of the seedlings. The hypocotyls may reach a length of somewhat more than 46 cm. before the abscission of the cotyledons releases them, allowing them to plummet to the mud or water beneath. The planting of the seedlings by their plunge into the tidal mud has been described by numerous writers, and in recent times has been doubted by Davis (2) and Egler (3) and reaffirmed by LaRue and Muzik (9). It is evident that the seedlings can be planted firmly in soft mud, but probably cannot be anchored in mud covered by water more than 10–20 cm. deep.

We have observed mangroves on various tropical shores and, besides being interested in the method of planting of mangrove seedlings, we have for some time wanted to find out at what age or size these curious embryos, or seedlings, are able to root if removed from the parent and planted.

Another question is that of the degree of regeneration of which *Rhizophora mangle* is capable. So far as we have been able to learn, no study of regeneration whatever has been made previously on the genus Rhizophora, or for that matter on any of the mangroves.

* Paper No. 963 from the Department of Botany, University of Michigan.

TABLE I

ROOTING OF MANGROVE SEEDLINGS IN SAND WET WITH FRESH AND WITH SALT WATER

Fresh-water cultures

Group	Number of days after planting			
	27	42	56	61
1. 15–30 cm. long ...	5 plants 1 had 2 roots 1 had 3 roots 1 had 4 roots 1 had 5 roots 1 had 6 roots	5 plants 1 had 3 roots 1 had 4 roots 2 had 6 roots each 1 had 7 roots (Longest root 3 cm., with many branches)	5 plants 1 had 6 roots 3 had 7 roots each 1 had 8 roots (All roots healthy and growing)	5 plants No change except roots were longer
2. 10–14 cm. long ...	7 plants No roots	6 plants 1 had 3 roots 2 had 4 roots each 1 had 5 roots 1 had 6 roots	6 plants 2 had 4 roots each 2 had 5 roots each 1 had 7 roots 1 had 8 roots	6 plants 2 had 4 roots each 1 had 5 roots 1 had 6 roots 1 had 7 roots 1 had 8 roots
3. 5–9 cm. long	12 plants No roots	11 plants 1 had 2 roots 1 had 3 roots 1 had 4 roots	10 plants 1 had 1 root 2 had 2 roots each 1 had 5 roots	10 plants 1 had 1 root 1 had 2 roots 1 had 3 roots 1 had 5 roots

Salt-water cultures

Group	Number of days after planting			
	27	42	56	61
1. 15–30 cm. long ..	5 plants 1 had 1 root	4 plants 2 had 1 root each 1 had 4 roots 1 had 5 roots	4 plants Withering, no further outgrowth of roots	Further degeneration
2. 10–14 cm. long ..	12 plants No roots	6 plants 1 had 1 root 2 had 2 roots each 1 had 4 roots	6 plants 2 had 2 roots each 1 had 2 roots 2 had 3 roots each	All dead
3. 5–9 cm. long	12 plants No roots	10 plants No roots	3 plants No roots	All dead

Experiments with Rooting

A number of seedlings of *Rhizophora mangle* were obtained from a mangrove swamp and were sorted into five size groups, as follows: (1) 15–30 cm. long; (2) 10–14 cm. long; (3) 5–9 cm. long; (4) 1.5–4 cm. long; (5) ±1 cm. long.

Each of the five groups was again divided into two, so that one set could be planted in sand wet with fresh water and the other in sand wet with salt water. For the fresh-water set a greenhouse flat was filled with sand and then put in a steel drum of fresh water, so as to be kept wet at all times. For the salt-water set a similar flat was used, but it was set in a drum filled with salt water from the water front at Mayaguez. The salinity of the open sea at Mayaguez varies from 35 to 38 per cent; the temperature there ranges from 25° to 30° C.; and the pH ranges from 7.5 to 8.1.

The results of the trials with the three larger size groups in both fresh and salt water are given in Table I; the seedlings in the two smaller size groups promptly declined and died, and are accordingly omitted from the table. Plate I, Figure 1, shows seedlings that were planted in sand wet with fresh water. The salt-water sets rooted very poorly, and the seedlings wilted more than was expected. It has been thought by several writers, Winkler (13), Bowman (1), Davis (2), Egler (3), and others, that salt water is not needed by this mangrove, but merely tolerated, although Gleason and Cook (6) point out that it always grows farthest from shore of any mangrove. It may be that the sea water used in the drum containing the salt-water sets actually became toxic, because it did develop a heavy scum on the top and was stagnant. Neither it nor the fresh water used was circulated or aerated in any way.

A second lot of seedlings was collected and sorted into the following size groups: (1) 22–31 cm. long; (2) 15–20 cm. long; (3) 9–14 cm. long; (4) 4–6 cm. long; (5) 1–3 cm. long.

Each group was then divided into two sets. All were planted in tidal mud in the mangrove swamp from which the seedlings were secured. One set was planted in half shade, and the other in the open, in full sun. The results are shown in Table II, except for the two groups of smaller seedlings, which died almost immediately and so are excluded.

It is to be noted that these seedlings rooted more rapidly than

TABLE II

MANGROVE SEEDLINGS ROOTED IN SWAMP MUD

Seedlings planted in half shade

Group	After 14 days	After 45 days
1. 22–31 cm. long		
6 without fruits	1 had 3 roots 3 had 4 roots each 1 had 5 roots 1 had 6 roots	1 had 5 roots 1 had 8 roots 2 had 9 roots each 1 had 10 roots 1 had 11 roots
10 with fruits	2 had 1 root each 4 had 4 roots each 1 had 5 roots	1 had 2 roots 1 had 3 roots 1 had 4 roots 1 had 5 roots 1 had 6 roots 1 had 7 roots 1 had 8 roots 1 had 9 roots
2. 15–20 cm. long		
10—all with fruits	1 had 1 root 1 had 3 roots	2 had 3 roots each 2 had 4 roots each 1 had 5 roots
3. 9–14 cm. long		
14—all with fruits	No roots	5 alive, no roots

Seedlings planted in full sun

Group	After 14 days	After 45 days
1. 22–31 cm. long		
7 without fruits	1 had 2 roots 1 had 4 roots 3 had 6 roots each 1 had 7 roots	1 had 2 roots 2 had 3 roots each 1 had 5 roots 1 had 8 roots 1 had 10 roots 1 had 11 roots
10 with fruits	4 had 1 root each 1 had 2 roots 2 had 3 roots each 1 had 4 roots	1 had 1 root 2 had 4 roots each 1 had 5 roots 2 had 6 roots each 2 had 7 roots each 2 had 8 roots each
2. 15–20 cm. long		
10—all with fruits	1 had 1 root	2 had 2 roots each 3 had 4 roots each 1 had 9 roots
3. 9–14 cm. long		
13—all with fruits	No roots	8 alive, no roots

TABLE III

DATA CONCERNING THE WATER IN JOYUDA LAGOON*

Date	Salinity (percentage)	Temperature (Centigrade)	pH
January 13, 1950	27.1	23.5°	7.8
May 11, 1950	26.5	27.5°	8.1
May 25, 1950	25.0	30.0°	8.2
June 16, 1950	28.2	30.5°	8.1
July 20, 1950	26.1	29.5°	7.9
September 7, 1950	24.0	31.0°	8.2
November 27, 1951	15.0	27.0°	8.2
January 9, 1952	17.8	25.0°	8.2
January 29, 1952	16.6	25.0°	8.2

* Data obtained from Dr. Norman T. Mattox.

even the fresh-water set (Table I). They were planted in mud in Joyuda Lagoon, where there is but slight tidal action and where the connection with the sea is only through a narrow channel. The salt concentration in this lagoon (see Table III) is lower than that in the water from the open sea which was used in the first experiment. The later experiment shows the rapidity with which the preformed roots on the ends of seedlings of good size can grow out.

In another experiment 40 large seedlings were collected, all of them over 20 cm. in length. These seedlings were divided into two groups: those from which the fruits were detached by abscission of the cotyledons and those with fruits intact. Each of these two groups was subdivided into a set moistened with salt water and a set moistened with fresh water. The results are given in Table IV. In the fresh-water set, again, the development was prompt, though less so than in the seedlings rooted in swamp mud (Table II). There is some indication that the presence of the fruits on the upper parts of the seedlings gives an advantage in rooting, although no such effect is shown in Table II. The salt water used was that from the open sea, as was that used for the salt-water seedlings considered in Table I, which inhibited root development completely.

In another experiment 60 large seedlings were collected, all over 20 cm. in length. A piece 5 cm. long was cut from 10 of these seedlings and the fruit was removed. The remaining 50 were divided into five lots of 10 each, and pieces 5 cm. long were cut from the root tips of the seedlings in four of these lots. After three of the four lots

TABLE IV

ROOTING OF MANGROVE SEEDLINGS (OVER 20 CM. LONG) WITH AND WITHOUT FRUIT, IN SAND WET WITH SALT AND WITH FRESH WATER

Seedlings planted in sand wet with salt water

Group	Number of days after planting				
	13	18	27	34	43
1. Fruits removed, 10 plants in all	No roots	No roots	No roots	No roots	Wilting badly, no roots
2. Fruits left on tops of seedlings, 10 plants in all	No roots	No roots	No roots	No roots	Wilting badly, no roots

Seedlings planted in sand wet with fresh water

Group	Number of days after planting				
	13	18	27	34	43
1. Fruits removed, 10 plants in all	No roots	1 had 1 root	1 had 1 root 1 had 3 roots	2 had 1 root each 1 had 4 roots 1 had 6 roots	1 had 1 root 1 had 2 roots 1 had 5 roots 1 had 6 roots
2. Fruits left on tops of seedlings, 10 plants in all	No roots	1 had 3 roots 1 had 4 roots	1 had 1 root 1 had 2 roots 1 had 4 roots 1 had 6 roots (1 root nearly 1 cm. long)	5 had 1 root each 1 had 7 roots 1 had 9 roots (3 roots over 1 cm. long)	1 had 1 root 1 had 2 roots 1 had 5 roots 1 had 8 roots 2 had 9 roots each (All roots were longer and stronger than in the group without fruits)

had been treated with hormone applications, both the hypocotyls and the tips of the four lots were planted in sand kept moist with fresh water. The one lot of 10 seedlings that was left uncut was treated with 0.1 per cent indolebutyric acid, with the hope that this lot might give an idea of optimum rooting performance. Table V shows the effects of the hormone applications. It appears that the presence of the fruits on the seedlings is beneficial to root regenera-

tion as well as to the outgrowth of preformed roots (which was evident in Table IV, also, but not in Table II).

Table VI shows the results of placing sets of seedlings in damp chambers after subjecting them to different treatments. Seedlings as small as 5 cm. long may produce roots under such circumstances. Fruits left intact on seedlings may exert a slight influence, though there is no certainty that that is the case. As in other experiments, the growth hormones were found to have a definitely inhibitory effect on root development in this species.

The Ability of Mangroves to Withstand Adverse Conditions

Nineteen fresh, mature embryos of *Rhizophora mangle* had a weight of 336.7 gm. when picked. They were weighed daily for sixty-eight days, during which time they lay on a laboratory bench. Loss of weight was slow but very regular, averaging 0.08 gm. a day for each embryo, or about 0.5 per cent. Roughly one third of the weight was lost in this period, and the embryos became flaccid and withered. Ten were planted at this time (sixty-eight days after removal from the tree), and all survived and grew. It was possible to note an increase in turgidity within two days after planting the bases in sand. The other 9 were planted fifty-six days later. These had lost more water and weighed 91.3 gm., an average of 10.1 gm. each, or about five ninths of their original weight. Of these, 6 survived for three months, but finally died.

Davis (2) and Egler (3) state that mangrove embryos usually land flat in the water when they fall from the tree, and later straighten up, but we found (9) that they usually fall straight down. An experiment was devised to shed additional light on this question and to determine the effect of different methods of planting on growth and survival. Seven groups of 10 embryos each (all of which had been marked off in centimeters) were treated as follows:

A—embryos laid horizontal on surface of sand
B—embryos placed at 45-degree angle with bases stuck in sand
C—embryos in vertical position, 5 cm. deep in sand
D—embryos floated in 7.5 cm. of water
E—embryos stuck vertical in 7.5 cm. of water
F—embryos placed at 45-degree angle in 7.5 cm. of water
G—embryos immersed, vertical, with tips 10–20 cm. below surface of water

TABLE V

EFFECTS OF HORMONE APPLICATIONS ON ROOTING OF MANGROVE HYPOCOTYLS OVER 20 CM. LONG AND EXCISED STEM TIPS 5 CM. LONG IN SAND WET WITH FRESH WATER

Lot (10 pieces in each)	Treatment	After 27 days	After 34 days	After 45 days	After 121 days
A	5 cm. cut off, fruits removed	1 had 1 root 1 had 2 roots	2 had 1 root each 2 had 2 roots each 1 had 3 roots 1 had 4 roots	1 had 2 roots 4 had 3 roots each 2 had 4 roots each 1 had 5 roots	2 had 3 roots each 3 had 4 roots each 3 had 5 roots each
B	5 cm. cut off, fruits left on	1 had 1 root	3 had 1 root each 2 had 2 roots each 2 had 3 roots each	2 had 2 roots each 3 had 3 roots each 2 had 4 roots each 1 had 5 roots	2 had 3 roots each 4 had 4 roots each 1 had 5 roots 2 had 8 roots each 1 had 9 roots
C	5 cm. cut off, fruits left on, cut lower ends dipped in 0.1% indoleacetic acid in lanolin	1 had 1 root	1 had 1 root	1 had 1 root 1 had 2 roots	2 had 1 root each 1 had 2 roots 3 had 3 roots each 1 had 5 roots
D	5 cm. cut off, fruits left on, cut lower ends dipped in 0.1% indolebutyric acid in lanolin	No roots	No roots 3 had strong basal swellings	1 had 1 root Basal swellings reduced	2 had 1 root each 1 had 2 roots 3 had 3 roots each 1 had 5 roots

E	5 cm. cut off, fruits left on, cut lower ends dipped in 0.1% naphthalene acetic acid	No roots	No roots 5 had basal swellings	1 had 3 roots Most had basal swellings	2 had 1 root each 1 had 2 roots 1 had 3 roots 1 had 4 roots
F	Root tips not cut, fruits left on, tips dipped in 0.1% indolebutyric acid	1 had 2 roots 2 had 3 roots each 2 had 5 roots each 2 had 6 roots each	1 had 2 roots 2 had 4 roots each 1 had 5 roots 1 had 6 roots 1 had 7 roots	2 had 2 roots each 1 had 3 roots 1 had 4 roots 1 had 5 roots 1 had 6 roots	1 had 2 roots 3 had 3 roots each 1 had 4 roots 1 had 5 roots 1 had 6 roots 1 had 7 roots 1 had 8 roots
G	Excised 5-cm. root tips buried in sand, with upper ends barely exposed	1 had 1 root	1 had 4 roots	1 had 5 roots 1 had 6 roots	3 had roots 2.5 cm. long 2 had roots 3 cm. long 2 dead
H	Same as for G, upper end dipped in 0.1% indoleacetic acid in lanolin	No roots	No roots	No roots	1 had roots 2.5 cm. long 5 dead
I	Same as for G, upper end dipped in 0.1% indolebutyric acid in lanolin	No roots	No roots	No roots	No roots
J	Same as for G, upper end dipped in 0.1% naphthalene acetic acid	No roots	No roots	No roots	No roots

TABLE VI

ROOTING OF MATCHED SETS OF MANGROVE SEEDLINGS FROM 5 CM. TO 12.5 CM. IN LENGTH PLACED ON MOIST FILTER PAPER IN DAMP CHAMBERS

Set (23 seedlings in each)	Number of days in damp chamber					
	13	27	44	71	121	224
1. Controls, fruits left on, no treatment	No roots	Largest one had 2 roots	2 had 2 roots each	1 had 1 root 1 had 3 roots 2 had 4 roots each 5 had 2 roots each 1 had 6 roots	7 had 2 roots each 2 had 3 roots each 2 had 4 roots each 1 had 5 roots 2 had 6 roots each	8 alive 2 had 2 roots each 1 had 3 roots 1 had 4 roots 2 had 5 roots each 1 had 8 roots 1 had 10 roots
2. Fruits removed, no other treatment	Largest one had 3 roots	1 had 3 roots	Largest one had 5 roots 1 had 1 root	1, only 5 cm. long, had 1 root 2 had 2 roots each 1 had 3 roots 1 had 5 roots 1 had 2 roots	2 had 1 root each 1 had 3 roots 2 had 4 roots each 1 had 8 roots 1 had 2 roots	9 alive 2 had 4 roots each 1 had 6 roots 1 had 8 roots 1 had 1 root 4 had no roots
3. Tips dipped in 0.01% indole-acetic acid in lanolin	No roots	No roots	No roots	No roots	13 had very short roots	4 alive 1 had 1 root 1 had 2 roots 1 had 4 roots
4. Tips dipped in 0.01% indole-butyric acid in lanolin	No roots	No roots	No roots	No roots	10 had very short roots 2 had 1 good root each 1 had 3 roots	6 alive 1 had 1 root 1 had 2 roots 1 had 4 roots
5. Tips dipped in 0.01% naphthalene acetic acid in lanolin	No roots	No roots	No roots	No roots	6 had very short roots 1 had 1 good root 2 had 4 roots each	3 alive 1 had 3 roots 2 had 6 roots each

No difference was seen between growth in sand and in water except that the roots of embryos lying on sand had difficulty penetrating into the sand and the entire base of the embryo was often raised 5–15 cm. from the ground. In some specimens growth was delayed several weeks longer than in those planted in water and soft mud.

The vertical embryos grew first. They rooted in two weeks, but growth took place only in the stem (not in the hypocotyl). Those floating had a few roots in one month.

In embryos laid flat or planted at a 45-degree angle, growth occurred in the hypocotyl in the region of the second to the fifth centimeter (mostly in the third centimeter) from the radicle until the plant straightened up. Although embryos which fall flat are able to straighten up and grow normally, they are delayed as compared to erect seedlings.

Seedlings floating in water or lying flat produced roots only on the downward side. The base of the hypocotyl sank till it touched bottom, but the apex still floated. Growth occurred about from two to six weeks after it did in those placed vertically.

The embryos completely immersed in water produced roots in two months after planting and shoots in four months. The leaves were normal in shape but slightly smaller than those on embryos under natural conditions.

The ability to grow even when immersed in water for months demonstrates a remarkable capacity in these seedlings for anaerobic respiration. This ability, together with the unusual tolerance to drying, is probably important in the survival and dissemination of the mangrove, especially in areas which are seasonally inundated.

Our experiments also indicated an ability to grow in fresh water, although this plant normally lives on the edges of salt marshes or oceans. Mature embryos were planted at a number of fresh-water and salt-water sites to allow us to compare growth and survival under these conditions. Nearly all were doing well after a period of eight months.

Regeneration of Pieces of Hypocotyls

In Table V and in Plate I, Figure 2, evidence is given of the very ready regeneration of new roots on the lower ends of cut-off hypocotyls. The 5 cm. piece which was cut off removed the radicle and all preformed branch roots completely; all the roots produced in lots

A, B, C, D, and E (Table V) were regenerated roots. In lot F the radicles were not removed, and all or most of the roots which appeared were preformed roots. Regenerated roots were produced in only slightly more time than it took for the roots in lot F to grow out, though it is to be suspected from other results that even indolebutyric acid slightly delays root outgrowth in mangrove. It is certain, then, that roots are regenerated from the lower hypocotyl in abundance, and in a rather short time. It was noted, also, that these roots were usually fatter and sturdier than the lateral roots that grew out from the radicle.

Hypocotyls were cut into 5 cm. lengths and placed on wet filter paper in Petri dishes. After 81 days one piece had produced two healthy roots at the lower end. After 234 days the specimen which had earlier formed two roots had three roots, and another had thrown out two roots. Other pieces of hypocotyl 5 cm. long were split in half lengthwise at the beginning of the experiment, but though these were still alive after 234 days, they had not rooted. From the slow rate of root formation it appears that 5 cm. is near the minimum length for a piece of hypocotyl to be capable of root regeneration.

In Table V, lots G, H, I, and J were composed of 5 cm. root tips cut from hypocotyls of mature size (over 20 cm. long). The 10 root tips in lot G were not treated, and, of these, 5 had formed roots after 121 days. One tip from lot H (treated with 0.1 per cent indoleacetic acid) had formed roots after 121 days. The tips in both G and H remained alive, and after 225 days a bud appeared on one tip of lot G. Since these tips were only 5 cm. long and a part of this length was radicle, it is plain that buds can be regenerated from pieces of hypocotyl measuring slightly less than this, and that buds can be regenerated from pieces of hypocotyl taken either from near the cotyledons or from the extreme lower end, near the radicle.

The longest seedling we found was 46.5 cm. long, and nearly all of this was hypocotyl. A set of 30 seedlings growing vigorously in tidal mud was measured from cotyledonary scars to the mud below. This distance ranged from 11 cm. to 34 cm., and the average for the 30 was 24.13 cm. We (9) found that one seedling dropped repeatedly from a height of 2 meters penetrated the mud 4.87 cm., on the average. Another had an average penetration of 4.6 cm., and a third, an average of 5.06 cm. Combining these three results gives an average of

4.84 cm. Not all this should be added to the 24.13 cm., however, for the terminal part is radicle. But this part certainly does not exceed 1.84 cm., on the average, so we may add 3 cm. to the 24.13 cm., to get 27.13 cm. as a rough average. As was stated above, the longest seedling we found was 46.5 cm. long. All this proves that the hypocotyls of the red mangrove are unusually long and strong.

An examination of seedlings naturally planted in the swamp showed that many had lost the bud which had represented the plumule and had regenerated one or two new buds each. A large number of normal seedlings, naturally rooted in the mud, were then decapitated by us. Some of these later disappeared, for various reasons, but after 140 days nearly all were found to have regenerated from one to three or more buds each. Regeneration of buds on hypocotyls of woody plants is very uncommon. It has been reported for *Anona muricata* by Mendel (10), who thought its occurrence there to be unique in woody plants.

Regeneration of Prop Roots

A large number of prop roots which had become well established in the mud were severed a short distance below the points of emergence from the branches of the parent plants. It was thought that the upper ends of the detached roots might produce new buds. However, after more than 230 days, no buds had been formed on the rather large number of roots which were cut. As might have been expected from the branching habits of these roots, the stubs of roots attached to the stems and branches formed one to two roots each, just above their severed ends (after a period of more than 200 days). Bowman (1) reported that side roots developed rapidly on prop roots whose tips had been injured. The prop roots in our experiments were cut off far back from the tip, but the development of branch roots was eventually the same as in those observed by Bowman.

Trials with Cuttings of Branches

Since prop roots are formed by the stems and branches of almost all sizes of trees of this species, some of them emerging as much as 4 meters above the mud or water, it was thought that stem cuttings would regenerate roots readily. Trials were made with three sets of

green-wood cuttings. In two of these sets the youngest pair of leaves was left intact on each cutting and all the other leaves were removed. One lot was planted in sand, and the second was put in fresh water. The third set of cuttings had all the leaves removed, but the terminal buds were left in place. A fourth set of cuttings was made from hard wood, with no leaves. These were all planted in sand.

It is surprising that none of these cuttings produced roots. Growth was limited to the production of a new pair of terminal leaves in a few specimens.

Regions and Rates of Growth in Hypocotyls

A set of 10 hypocotyls on parent trees were measured and marked off in centimeters; they ranged from 3 to 21 cm. long. The hypocotyls were remeasured after fifteen days and again after another month.

It was found that in hypocotyls originally as short as 3 cm. the tip centimeter had ceased to grow, but that growth occurred throughout the remaining length and was most rapid in the basal segment. Seedlings 8–12 cm. long showed very slight growth in the terminal 6 cm. and the greatest growth in the basal centimeter. Hypocotyls over 15 cm. long showed no growth at all except in the basal centimeter. Seedlings 3–6 cm. long averaged 3.44 mm. elongation a day; those 8–12 cm. long averaged 4.38 mm. of growth a day; and those over 15 cm. long grew very slowly indeed, with an average elongation of only 0.64 mm. a day. These last embryos had nearly finished their growth. The two younger groups were still growing rapidly and were increasing their lengths by about the same daily increment. But, of course, this manner of comparing the seedlings gives an erroneous idea of their actual growth rates, since an embryo 3 cm. long at first measurement increased its length more than fivefold, whereas one 12 cm. long at the start was far short of doubling its length. Evidently the growth rate falls off rapidly when the hypocotyls reach a length of about 15 cm., though in extremely large seedlings it is safe to say that a rapid growth is kept up until the hypocotyls are as much as 30 cm. long.

Measurements of embryos begun when the radicles were 1 mm. long indicate a maturation period of from three to four months, although Gleason and Cook (6) state that they may hang on for a year or more.

Tissue-Culture Trials

Numerous attempts were made to induce growth in tissues of *Rhizophora mangle* in vitro on various culture media. The tissues are extremely full of tannic acid, as Bowman (1) has shown in detail and as the use of this species in cutch testifies (Hill, 7). Cut surfaces blacken rapidly, and the tissues degenerate and die in a short time.

Tissues used in the trials were root tips, stem tips, endosperm, young embryos, and cotyledons. None of these showed any growth in culture.

Growth of Hypocotyls from Fruits after Emerged Tips Have Been Excised

Numerous wounded seedlings were found on the trees, and on some of these the entire tip portion had been cut off by insects. Some of the wounded seedlings were dying when found, but others appeared capable of further growth on the parent plant. To test the ability of wounded seedlings to remain on the tree and to grow from the base after the greater part of the hypocotyl had been excised from each, a total of 50 seedlings were sheared off flush with the lower part of the fruit. Thus all of each hypocotyl was removed except the short basal meristematic region next to the cotyledon. Each hypocotyl was measured before excision and each was tagged with a number. One group of 25 seedlings was kept as a control; in the second group of 25, the fruits with the stubs of hypocotyls emerging from them were thoroughly coated with lanolin containing 0.01 per cent indoleacetic acid, to aid in holding the fruits on the trees. (This trial obviously came to mind because of the senior author's experience in keeping Coleus petioles on the stem by the use of growth hormones [8]. Later Gardner and Marth [4], Gardner, Marth, and Batjer [5], Murneek [11], and many others showed the effectiveness of growth hormones in controlling preharvest drop in apples.) The results of this experiment are given in Table VII. Only those fruits which were still on the trees after sixty-six days are included in the table.

The data given in Table VII answer the question as to the ability of hypocotyls to continue basal growth after the excision of all of the emerged portion. In spite of the very drastic treatment, some of the seedlings produced a remarkable amount of growth. The results indicate, also, that indoleacetic acid interferes with both growth of hypocotyls and retention of fruits on the trees.

TABLE VII

BASAL GROWTH OF MANGROVE HYPOCOTYLS AFTER ABSCISSION OF ALL PARTS OF HYPOCOTYLS WHICH HAD EMERGED FROM THE FRUITS

(Total length is original length plus basal growth; all measurements are in centimeters.)

Controls, no further treatment after abscission

Original length	Basal growth after 66 days	Basal growth after 91 days	Total length of hypocotyls
4.5	5.7	...	...
5.2	4.0	...	...
3.0	6.0	8.8	11.8
2.8	4.5	7.5	10.3
11.0	5.0	9.0	20.0
1.0	4.2	9.4	10.4
1.5	5.6	8.1	9.6
2.8	3.0	5.0	7.8
6.2	2.9	...	...
5.5	4.0	...	...
5.7	4.4	...	...
5.0	4.5	...	...
2.6	4.9	6.9	9.5
8.6	6.0	9.0	17.6
9.6	5.0	6.9	16.5
5.5	6.0	10.6	16.1
Av. 4.4	Av. 4.73	Av. 8.12	Av. 12.5

Fruit treated with 0.01% indoleacetic acid in lanolin

Original length	Basal growth after 66 days	Basal growth after 91 days	Total length of hypocotyls
4.5	4.2	...	...
4.9	3.3	...	...
2.5	4.0	5.6	8.1
5.4	5.2	...	...
6.1	6.0	...	...
3.0	5.9	9.4	12.4
4.9	3.1	...	...
6.0	3.4	6.9	12.9
3.2	4.9	...	...
Av. 4.5	Av. 4.44	Av. 7.3	Av. 11.8

Another experiment, very similar to the preceding one, was based on 22 seedlings of lengths which varied considerably, but perhaps less than those shown in Table VII. Of the 22 seedlings 10 remained on the trees and grew, and these averaged 8.0 cm. in length at the start, whereas the seedlings considered in Table VII had an average length of only 4.45 cm. The treatment of these seedlings was less drastic than that used in the preceding experiment, for they were merely cut back to a length of from 0.5 cm. to 2.0 cm. The small amount of

TABLE VIII

BASAL GROWTH OF MANGROVE HYPOCOTYLS FROM WHICH A PART OF THE TIP END HAD BEEN EXCISED

(All measurements are in centimeters.)

Original length	Length after excision	Length after 42 days	Length after 111 days	Length after 142 days	Total length (original length plus growth in 142 days)
8.0	1.0	7.5	16.5	16.5	23.5
8.5	2.0	9.5	17.5	17.5	24.0
11.5	2.0	13.0	13.0	13.0	22.5
5.5	1.0	8.0	17.5	20.0	24.5
6.5	2.0	9.5	17.5	17.5	22.0
11.0	1.0	7.5	7.5	7.5	17.5
9.5	2.0	10.5	17.5	17.5	25.0
10.0	2.0	9.0	18.0	18.0	26.0
7.0	1.0	...	...	28.0	34.0
2.5	0.5	5.5	15.5	18.5	20.5

emerged hypocotyl which was left intact on each appears to have been very important, for, as shown in Table VIII, the growth of the hypocotyls left after excision was really remarkable. One actually produced 28 cm. of new growth after it had been cut back to a length of 1 cm. The portion excised was 6 cm. long, so the total growth of the hypocotyl was 34 cm., which is longer than the average undisturbed seedling ever gets. It was stated above that most of the growth of the hypocotyls is basal, and this experiment gives further evidence of the truth of that statement. The growth shown in Table VIII seems truly remarkable in view of the excision of the greater portion of each hypocotyl. Unfortunately, we cannot compare it with

that of hypocotyls of other plants, for no seedling known to us compares with this huge, overgrown mangrove seedling, with its very long and thick hypocotyl and its source of food in the parent plant. This growth was neither regeneration nor restitution, but simply a continuation of the original growth, with scarcely any disturbance due to the drastic excision practiced on these seedlings.

Grafting in Seedlings

The growth indicated in Tables VII and VIII showed that seedlings of the red mangrove are remarkably insensitive to trauma, and, although no grafts were found anywhere on the trees, it was thought that the seedlings might respond to grafting. Seedlings of many species should be good materials for grafting because juvenile tissues are more responsive, usually, than older ones. Such tissues regenerate roots more readily, and cuttings from young plants of many species root easily, while those from old plants root with difficulty, or not at all. Muzik (12) found *Hevea brasiliensis* to be a particularly good example of this, for he rooted cuttings of very young seedlings without any trouble. But only rarely has anyone been able to root cuttings of branches of older trees. The senior author has made many trials of this type of grafting, with only very limited success. The mangrove seedling, as has been mentioned before, cannot be compared with any other seedling, and it is not small or delicate. It was found extremely easy to make any type of graft with it that could be imagined. Grafts were made of upper ends on lower ends of hypocotyls and of lower ends on upper ends; two lower ends were put together, forming a plant with two plumules and no radicle, and, conversely, two upper ends were joined, making a plant with two radicles and no plumule. Hypocotyls were joined together side by side, giving a Siamese-twin type of seedling. Another pair were joined with the plumule of one alongside the radicle of the other. Plumules were set in the sides of some seedlings, and extra radicles in others. All of the grafts, however bizarre, united—some examples are shown in Plate II. It would be difficult to find any material which grafted more easily and more promptly than these seedlings.

Summary

1. Viviparous embryos of the red mangrove are capable of rooting at an early age if removed from the trees and planted in sand mois-

tened with fresh water. Hypocotyls no more than 5 cm. in length have been rooted. These roots are preformed in the tip of the radicle.

2. Rooting and early growth is usually more successful in fresh water than in salt water.

3. New roots are readily regenerated from the lower ends of cut hypocotyls; they are never regenerated from the upper ends of pieces of hypocotyl. Excised lower ends of hypocotyls bearing the radicles intact root readily even if only 5 cm. long. Pieces of hypocotyl 5 cm. long and without radicles form roots, but require a considerable time. Rooting was as good from one piece of hypocotyl as from another. No differences were found between pieces cut from just above the radicles, from the midportion of the hypocotyl, or from just below the cotyledons.

4. Seedlings growing in the mud which had the plumules removed by cutting through the upper ends of the hypocotyls regenerated from one to three, or even more, buds after 140 days. Pieces of hypocotyl less than 5 cm. long with intact radicles regenerated buds at their upper ends in 225 days. Buds can be formed from any portion of the hypocotyl, upper, middle, or lower, but they are always situated on the upper ends of the pieces.

5. When prop roots well rooted in the mud were severed, from one to three roots each were formed on the lower ends of the upper parts, which were still attached to the trees. This process took over 200 days. The lower pieces of the prop roots, no longer attached to the trees but anchored in the mud, formed no buds even after a period of 230 days.

6. Cuttings were made from hard wood and green wood, and with and without leaves. Some were planted in sand and others in fresh water. No roots were formed on any cuttings.

7. In hypocotyls 3 cm. long, growth of the tip centimeter (radicle) had ceased. Seedlings 8–12 cm. long showed slight growth in the terminal 6 cm. and greatest growth in the basal centimeter. Hypocotyls over 15 cm. long showed growth only in the basal centimeter.

8. Trials at inducing growth in root tips, stem tips, endosperm, young embryos, and cotyledons all resulted in complete failure.

9. Mangrove seedlings showed remarkable resistance to drying out and also to immersion in salt water.

10. When the emerged hypocotyls are cut off flush with the lower ends of the fruits, the parts of the seedlings inside the fruit may con-

tinue growing if the fruit does not absciss. When cut back less drastically (with 0.5–2.0 cm. of hypocotyl left beyond the ends of the fruits), the growth is even more rapid and extensive. One seedling trimmed from 7 cm. to 1 cm. produced 28 cm. of growth after the trimming.

11. Plant-growth hormones were not beneficial in rooting hypocotyls, but, on the contrary, were somewhat inhibitory. They were of no benefit in holding fruits on the trees after the exposed hypocotyls had been cut off, and they did not stimulate the new basal growth of the excised hypocotyls.

12. The hypocotyls of the red mangrove can be grafted together in almost any way imaginable, though no natural graft was found on any tree.

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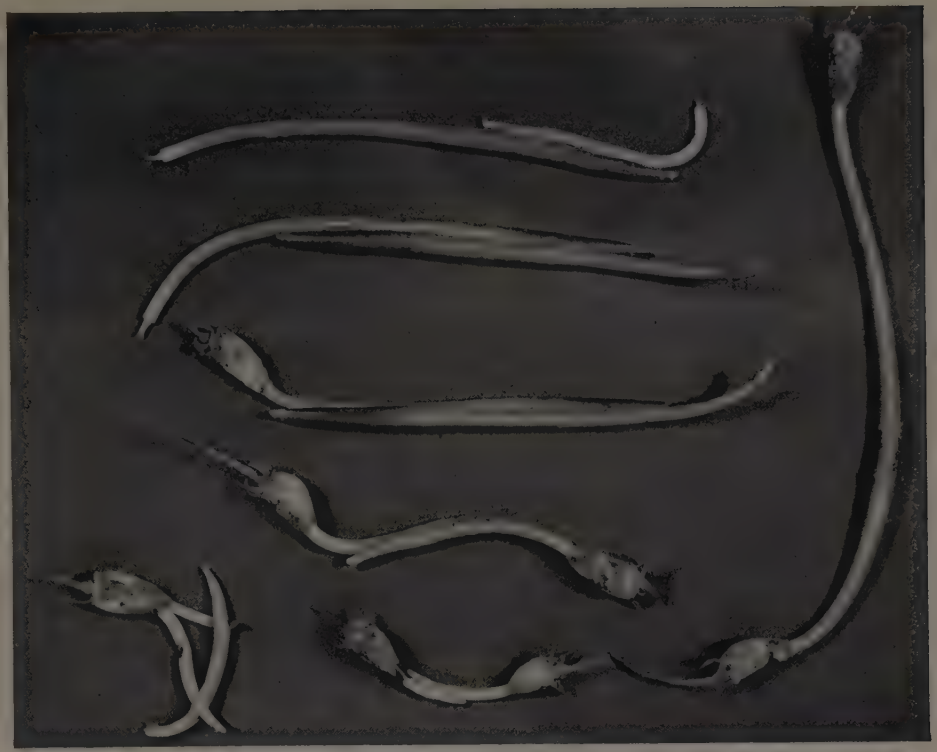
PLATES I–II

FIG. 1. Seedlings of red mangrove removed from parent plant and planted in sand wet with fresh water

FIG. 2. Seedlings of red mangrove from which a tip 5 cm. long has been removed. Hypocotyls and excised tips were planted in sand wet with fresh water. The roots produced on these hypocotyls are larger than those normally found on radicles from preformed primordia.



Hypocotyls of red-mangrove seedlings which have been grafted together in various positions

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STUDIES IN THE GENUS PORIA. V*

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THIS paper is a continuation of my studies of type specimens and other important collections of Poria. Eight species are here reduced to synonymy, one species is recorded with certainty for the first time in North America, and one is reported for the first time from nature.

I am indebted to the directors of the following herbaria for the privilege of studying specimens under their care: British Museum of Natural History, London, England (BM);[1] Division of Mycology and Disease Survey, Bureau of Plant Industry, Soils, and Agricultural Engineering, Beltsville, Maryland (BPI); Farlow Library and Herbarium of Cryptogamie Botany, Cambridge, Massachusetts (FH); Royal Botanic Gardens, Kew, England (K); Missouri Botanical Garden, St. Louis, Missouri (MO); New York Botanical Garden, New York City, New York (NY); and Pennsylvania State College, State College, Pennsylvania (PAC). Collections whose location is not indicated are in the herbarium of the College of Forestry, Syracuse, New York.

Poria demetrionis (Murr.) Sacc. & Trott.

This fungus, previously known only from a single collection, appears to be a resupinate condition of the widely distributed and common southern *Polyporus licnoides* Mont. and is therefore placed in synonymy with it. The fungus is variable and confusing in form; the northern collections have frequently been misidentified. One collection on sassafras (MO), identified by Peck as *Fomes ribis* (Schum.

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The first and third papers in this series were published in *Pap. Mich. Acad. Sci., Arts, and Letters*, 32: 99–101. 1948, and 33: 3–6. 1949; the second and fourth appeared in *Lloydia*, 10: 45–59. 1947, and 11: 163–170. 1948.

[1] The institutions are identified by the symbols recommended in *Index Herbariorum, Part I: The Herbaria of the World*, by J. Lanjouw and F. A. Stafleu (Utrecht, Netherlands, 1952).

ex Fries) Gill., was reported by Spaulding (1907). Subsequently it was referred by Overholts (1915, p. 50) to *P. licnoides*, along with another collection (No. 448) by Overholts (PAC), again on sassafras. Part of the latter collection was sent to Bresadola, who referred it to *Trametes rufi-tincta* (Berk.) Bres. and described it (Bresadola, 1920, p. 62) in some detail (citing the substratum in error as *Gymnocladus dioica*). Overholts' reference of these two collections to *P. licnoides* appears to be correct.

Poria humilis Murr.

A collection of this species, previously reported under the preempted name *Poria incrustans* (Berk. & Curt.) Cooke, was made in Tennessee (Lowe 3622). When fresh it was white, soft but leathery, without a distinctive taste, and readily separable. The fungus seems to be a valid but rarely collected species; specimens have been seen from New England, Virginia, and Tennessee.

Poria luteoalba (Karst.) Sacc.

This species is a fairly common and widespread fungus on the wood of conifers in the eastern United States. Representative collections are known from Ontario (Univ. of Toronto Cryptogamic Herb. No. 7799 [PAC]); Massachusetts (Spaulding 14 [State Univ. Iowa Herb.]); New York (Lowe 3268); Virginia (Lowe 3054); North Carolina (Lowe 2876); and Tennessee (Hesler 17240 [Herb. Univ. Tennessee]). The species is easily separated from other similar-appearing porias with cylindrical spores by the presence of very conspicuous encrusted cystidia. Identification was made by comparison with specimens loaned by Dr. John Eriksson, who has published an excellent account of this species (Eriksson, 1949, p. 15) and who kindly confirmed the determinations of a number of my specimens.

Some collections tentatively reported from Oregon (Baxter, 1932, p. 221) under this name seem to be of a quite different identity. Nearly noncystidiate specimens were named *Poria sinuascens* by Pilát (1940, p. 1) and by Overholts (1942, p. 37); the isotype collection (Overholts Herb. No. 7678 [PAC]) has typical cystidia. The cystidia are so few and so scattered, however, that they were not noted by either Pilát or Overholts, both of whom describe the sporophore as without cystidia. *P. sinuascens* therefore becomes a synonym of

P. luteoalba, and American collections are here cited for the first time under this name.

Poria oleracea David. & Lomb.

The original description of this fungus (Davidson *et al.*, 1947) was prepared from sporophores produced in culture, since fruiting bodies formed in nature were then unknown. Collections are now recorded on oak from New York (Lowe 3488, D. Richards 36), from Maryland (BPI), and from Tennessee (Lowe 3738). As originally described, the fungus is associated with a brown cubical rot.

Poria radiculosa (Peck) Sacc.

A collection made in New York (Lowe 3492) agrees in every detail with the original description, and with the fragmentary type material. The fungus is the same as *Poria luteofibrata* Baxter, a rather common species known over a wide area in the eastern United States. A culture obtained from Lowe 3492 by Mr. Ross Davidson of the Division of Forest Pathology, Beltsville, Maryland, was identical with a culture of *P. luteofibrata* originally isolated by Baxter. It appears certain, therefore, that these two species are synonymous; Peck's name is the earlier, valid one.

Poria rancida Bres.

Ontario and California collections of this species have been reported by Baxter (1937, p. 295). No additional American stations were known until it was noted that a fungous collection from Tennessee closely agreed with both the description of this species and that of *Poria cognata* Overh., described from Tennessee. Comparison of isotype material of *P. rancida* (NY) and the type of *P. cognata* (PAC) established that they are synonymous; the older, valid name is *P. rancida*.

Poria rufitincta (Berk. & Curt.) Cooke

The name *Poria rufitincta* has had a varied application, and, unfortunately, a study of the type material (K; isotypes, FH) does not resolve the confusion. Three specimens from Cuba are mounted on the right-hand side of the type sheet (Smith, 1901, p. 7). One is marked "var." and may be excluded from consideration since the

original description did not mention a variety. The other two are presumably the collections upon which the original description was based. Both of these specimens are sterile. The two appear to be different species, to judge by the difference in the size and the abundance of the setae.

The middle specimen on the right side of the type sheet seems to agree with the type specimen of *Poria castletonensis* (Murr.) Sacc. & Trott. and with the type specimen of *P. hondurensis* (Murr.) Sacc. & Trott. The type collection of *P. castletonensis* is fertile, the only one of all these that is, and therefore it is proposed to use this name for the fungus and to relegate *P. rufitincta* (pro parte) and *P. hondurensis* to probable synonymy.

The bottom specimen on the right side is sterile, and its identity is unknown.

The collection (BM; BPI) additionally reported in the original description (W. R. Elliott No. 346, from Dominica) appears to be *Poria graphica* Bres. A Missouri collection determined by Bresadola (1920, p. 62) is referred elsewhere in this paper to *Polyporus licnoides*. C. L. Smith No. 358, from Nicaragua (BPI), originally identified as *Poria rufitincta*, also belongs to that species.

Poria subambigua Bres.

Isotype material (BPI) of this species from Africa agrees with the type material of *Poria flaccida* Overh. (PAC) from Louisiana, and the latter species therefore is a synonym. The fungus is similar to *P. corticola* (Fries) Cooke, but lacks cystidia and has more nearly globose spores. It differs from *P. ambigua* Bres. by the same characters.

Poria umbrinella Bres.

Isotype material (NY) of this species from Brazil agrees with the type material of *Poria floridana* (Murr.) Sacc. & Trott., which is synonymous with *Fomitiporella langloisiana* Murr., *Fuscoporella coruscans* Murr., and *Fuscoporella mexicana* Murr. (Lowe, 1948). The earliest and the valid name for this species is *P. umbrinella*.

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SOME INTERESTING SPECIES OF BRYOPHYTES FROM ISLANDS IN LAKE ERIE

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IN JUNE of 1945 we spent approximately two weeks collecting bryophytes on the islands of western Lake Erie, making the Ohio State Fish Hatchery at Put-in-Bay, on South Bass Island, our headquarters. This group of islands includes South Bass, Middle Bass, North Bass, Gibraltar, Green, Ballast, Rattlesnake, Kelley's, and Starve. All are within the boundary of the United States, and all except Kelley's are in Ottawa County, Ohio; Kelley's is in Erie County, Ohio. The region is entirely underlaid with limestone—Kelley's Island by Corniferous limestone, which comes close to the surface over much of the island, and the Put-in-Bay group by the older Waterline formation. The limestone is covered for the most part with a thin layer of soil, but this is generally insufficient to support large trees. Conditions on the individual islands vary to some extent, as is indicated in the descriptions that follow.

South Bass Island is sparsely wooded except along the west side of the south half of the island; it has large areas in vineyards and many small pasture strips. There were few bryophytes in the woods, although we found Porella on a stone there and a great deal of Anomodon on a pile of stones in the woods behind the laboratory. Mnium and Brachythecium were found in the cemetery. The most profitable collecting, however, was done along the rocky shore—on stones and cliffs, and on the soil at the top of the cliffs. The island yielded a total of seventy-five species.

Middle Bass Island is quite low and level, with no steep cliffs or ledges, few wooded areas, and a sandy-clay soil. It is a very poor site for bryophyte collecting, although a large marshy area in the

southeastern part yielded *Riccia fluitans*. We found only forty-six species here, in all.

North Bass Island is even less favorable for bryophytes than Middle Bass. Big trees are rare, the soil is quite sandy, and large sections are under cultivation or in open pasture. Thirty-five species, only, were gathered here.

Gibraltar Island, in Put-in-Bay, is the site of the summer Biological Station of Ohio State University. It is not very large, but has high cliffs and many sizable offshore rocks. It is covered with open woods, and the soil in most places is sandy and well sodded. We chose a bright, windless day to go around the island by boat and collected fifty-two species from its cliffs and offshore rocks.

Green Island is heavily, and almost completely, wooded; ninebark clumps along its rocky shore are so dense that we could scarcely crawl through them. We found nothing in the woods but a very poor specimen of Dicranella. The rocks facing north are hard limestone and are well covered with many kinds of mosses, as well as with hepatics, lichens, and algae. The south-shore rocks, of softer sandstone, yielded several species of Bryum and Tortula. We had been told that there was an inland lake on the island, and spent some time looking for it. The effort was worth while. The basin of the lake, which is nearly circular and about thirty feet in diameter, is an old cave with the roof gone. It is connected by an underground tunnel with Lake Erie, so that the water is constantly rising and falling. The walls of the cave are completely covered with a mat of mosses. We made two short trips to this island and collected a total of sixty-four species in about six hours.

Ballast Island, lying southeast of Middle Bass Island, in the channel between Middle Bass and South Bass, is tiny, and completely wooded except for the open space near the dock and the clearings around the two little houses. We felt that we could have spent more time on this island, as well as on each of the others; nonetheless, in from two and one-half to three hours we collected thirty-six species here.

Rattlesnake Island, also, is very small, but it is completely grass-covered except for large elm trees growing all around the shoreline and a few scattered ones inland. It has high cliffs rising abruptly from the water along most of its shore. We did not have time to

circle the island, but collected specimens in a variety of habitats, including open meadows, low cliffs, ledges, and high cliffs. Particularly interesting are the crevasses, which were formed when large slabs of rock broke away from the main island but did not topple over; the deep, moist, dark fissures that resulted often reach to, or below, the water level. These are excellent collecting sites for bryophytes, and we got forty-eight species in about three hours.

Kelley's Island is the largest of all those we visited. It had mostly open fields, which are often merely overgrown quarries, although there are several large, densely wooded areas and some vineyards. The island is noted for the deep glacial grooves found there. Several of the abandoned quarries provided good collecting sites. In one of them we gathered our only specimen of the water moss *Drepanocladus aduncus*. *Campylium polygamum* and *C. stellatum* were also found, completely filling a small ditch leading from one quarry to another. *Leptodictyum riparium* covered the ground and rocks nearby. We spent about twelve and one-half hours on this island, collecting a total of fifty-nine species.

Starve Island, the smallest island we visited, has on it only three or four large elm trees and a clump of ninebark bushes. Yet we got thirty species here in about forty-five minutes. The surprisingly large number of species growing in this wave-washed, and often wave-lashed, area may be explained by the presence of hundreds of gulls and terns which use the island for a nesting place, scattering their nests on the open rocks and under the bushes. At the base of two ninebarks we found a specimen of *Tortula mucronifolia* Schwaegr.—our only one, although it formed a very large clump. It was on this island, incidentally, that we saw our first glacial grooves, looking as though they had been made by an automobile that had been driven in a straight line diagonally across the bare rock surface at a time when it was soft enough for the tires to leave an impression.

In all, we collected 108 species of mosses (representing fifty genera and sixteen families) and twelve species of hepatics (representing eleven genera and eight families). A list of the species not previously reported from Ohio is given below, and, after that, a systematic list (Table I, pp. 42–48) of all the bryophytes that we found on the various islands. To this list may be added the following species collected since 1945 by Dr. R. B. Gordon:

Sphagnum strictum Sull. Kelley's Island.
Gymnostomum recurvirostrum Hedw. South Bass.

At the end of this paper will be found an extended bibliography. We have a card catalog of all species of bryophytes mentioned in the literature as from Ohio, and will be glad to make it available to anyone interested. Each card contains the scientific name, as originally published, and a list of the studies mentioning the species.

We wish to express our thanks to Dr. W. C. Steere for suggesting the islands in Lake Erie as good collecting sites and for his aid in identifying several doubtful species; to Dr. T. H. Langlois, director of the Franz Theodore Stone Laboratory, for his advice and his thoughtfulness while we were on the islands; to Dr. C. F. Walker, Dr. M. B. Trautman, and Dr. O. B. Weeks for their patience in answering our many questions, their suggestions on possible habitats, and their help in getting us to those spots; and to Dr. R. T. Wareham for the use of his unpublished check list of Ohio mosses.

Species Not Previously Reported from Ohio

Didymodon rigidulus Hedw.—Wave-washed rocks. South Bass, Gibraltar, Rattlesnake, Kelley's.

Didymodon trifarius (Hedw.) Brid.—Exposed cliffs. Ballast, Rattlesnake.

Tortella caespitosa (Schwaegr.) Hampe.—Sandy soil at top of cliffs, usually in sod. South Bass, Green, Kelley's.

Grimmia alpicola Hedw.—Well-exposed shore rocks. South Bass, Gibraltar, Green, Ballast, Rattlesnake, Kelley's, Starve.

Grimmia apocarpa var. nigrescens Mol.—Well-exposed rocks. South Bass, Gibraltar, Green, Ballast, Kelley's, Starve.

Grimmia pulvinata (Hedw.) Smith.—On a small stone in shaded moist area just below glacial grooves (one small collection). Kelley's.

Brachythecium digastrum C. Müll. & Kindb.—Light, sandy soil. South Bass, Middle Bass, Ballast, Starve.

Campylium polygamum (Bry. Eur.) Bryhn.—Low wet areas among grasses. South Bass, Middle Bass, North Bass, Gibraltar, Green, Kelley's.

Hygrohypnum eugyrium (Bry. Eur.) Loeske.—Wave-washed rocks, among other mosses. South Bass, Gibraltar, Green.

Leskea nervosa (Schwaegr.) Myrin.—Shaded rocks. South Bass.
Chiloscyphus pallescens (Ehrh.) Dumort.—Rattlesnake.
Cololejeunea biddlecomiae (Aust.) Evans.—South Bass.
Porella platyphylloidea (Schwein.) Lindb.—Gibraltar, Rattle-Snake.
Preissia quadrata (Scap.) Nees.—South Bass, Green, Kelley's.
Ricciocarpus natans (L.) Corda.—North Bass, Kelley's.

TABLE I

BRYOPHYTES COLLECTED ON ISLANDS IN WESTERN LAKE ERIE, OHIO

Musci	South Bass	Middle Bass	North Bass	Gibraltar	Green	Ballast	Rattlesnake	Kelley's	Starve
Polytrichaceae									
Atrichum angustatum (Brid.) Bry. Eur.	×	..	..	..	..	..	..	..	..
Atrichum undulatum (Hedw.) Beauv.	×	..	..	..	..	..	..	..	..
Polytrichum juniperinum Hedw.	..	..	..	..	×	..	..	..	..
Fissidentaceae									
Fissidens cristatus Wils.	×	×	..	×	×	×	×	..	..
Fissidens minutulus Sull.	×	×	..	×	×	..	..	×	..
Fissidens obtusifolius Wils.	×	×	×	×	×	..	×	×	×
Fissidens osmundioides Hedw.	×	..	..	×	×	×	×	..	..
Fissidens taxifolius Hedw.	×	..	..	..	..	..	..	..	..
Fissidens viridulus (Web. & Mohr.) Wahlenb.	..	..	..	×	..	..	..	..	..
Ditrichaceae									
Ceratodon purpureus (Hedw.) Brid.	×	..	×	×	×	×	×	×	×
Seligeriaceae									
Seligeria calcarea (Hedw.) Bry. Eur.	..	..	..	..	..	..	..	×	..
Dicranaceae									
Dicranella cerviculata (Hedw.) Schimp.	×	..	..	..	..	..	..	..	..
Dicranella heteromalla (Hedw.) Schimp.	×	×	..	..	×	..	..	..	×
Dicranella varia (Hedw.) Schimp.	×	×	..	×	..	..	..	..	..
Dicranum fulvum Hook.	..	..	..	..	×	..	..	..	..
Encalyptaceae									
Encalypta streptocarpa Hedw.	×	..	..	..	..	..	..	..	..

Pottiaceae									
Barbula convoluta Hedw.	..	..	..	×	..	×	..	×	..
Barbula fallax Hedw.	×	..	×	×	×	..	×	×	..
Barbula unguiculata Hedw.	×	×	..	×	×	×	×	×	..
Desmatodon obtusifolius (Schwaegr.) Jur.	×	..	×	×	×	..	×	×	×
Desmatodon plinthobius Sull. & Lesq.	..	×	..	..	..	..	..	..	..
Desmatodon porteri James	×	×	×	..	×	..	×	×	×
Didymodon recurvirostris (Hedw.) Jenn.	×	×	×	×	..	..	×	×	×
Didymodon rigidulus Hedw.	×	..	..	×	..	..	×	×	..
Didymodon trifarius (Hedw.) Brid.	..	..	..	..	..	×	×	..	..
Gymnostomum aeruginosum Smith	..	..	..	×	..	..	..	×	..
Gymnostomum calcareum Nees & Hornsch.	×	×	..	×	×	×	×	×	×
Gymnostomum recurvirostrum Hedw.	..	..	..	..	..	..	×	×	..
Hyophila tortula (Schwaegr.) Hampe	×	..	×	×	×	×	×	×	×
Phascum cuspidatum Hedw.	..	×	..	..	..	..	..	..	..
Tortella caespitosa (Schwaegr.) Limpr.	×	..	..	..	×	..	..	×	..
Tortella tortuosa (Turn.) Limpr.	×	..	..	×	..	..	..	×	..
Tortula intermedia Brid.	..	..	..	×	..	..	..	..	..
Tortula mucronifolia Schwaegr.	..	..	..	..	..	..	..	..	×
Tortula ruralis (Hedw.) Smith	..	..	..	×	..	..	..	×	×
Trichostomum cylindricum (Bruch) C. Müll.	×	..	..	×	..	..	..	..	..
Weisia viridula Hedw.	×	×	..	×	×	..	..	×	..
Grimmiaceae									
Grimmia alpicola Hedw.	×	..	..	×	×	×	×	×	×
Grimmia apocarpa Hedw.	×	×	..	×	×	×	×	×	×
Grimmia apocarpa var. nigrescens Mol.	×	..	..	×	×	×	..	×	×
Grimmia pulvinata (Hedw.) Smith	..	..	..	..	..	..	..	×	..
Hedwigia ciliata Hedw.	×	..	×	..	..	..	..	..	..

TABLE I (*continued*)

Musci	South Bass	Middle Bass	North Bass	Gibraltar	Green	Ballast	Rattlesnake	Kelley's	Starve
Funariaceae									
Funaria hygrometrica Hedw.	×	×	×	×	×	×	×	×	×
Physcomitrium turbinatum (Mx.) Brid.	×	×	×	×	..	..	×	×	×
Orthotrichaceae									
Orthotrichum anomalum Hedw.	×	..	..	×	×	×	×	×	..
Orthotrichum ohioense Sull. & Lesq.	×	..	..	..	..	×	..	..	..
Aulacomniaceae									
Aulacomnium palustre (Web. & Mohr.) Schwaegr.	..	..	..	..	×	..	..	..	..
Bryaceae									
Bryum argenteum (L.) Hedw.	×	×	×	..	×	..	×	×	×
Bryum bimum Schreb.	×	×	..	×	×	×	×	×	×
Bryum caespiticium (L.) Hedw.	×	×	×	×	×	×	×	×	×
Bryum capillare (L.) Hedw.	×	×	..	..	×	..	..	×	×
Bryum cuspidatum (Bry. Eur.) Schimp.	×	×	×	×	×	×	×	×	..
Leptobryum pyriforme (Hedw.) Schimp.	..	×	×	×	..	..	×	×	×
Pohlia nutans (Hedw.) Lindb.	×	..	..	..	×	..	..	×	..
Pohlia wahlenbergii (Web. & Mohr.) Andrews	..	..	×	..	..	..	..	..	..
Rhodobryum roseum (Bry. Eur.) Limpr.	..	..	..	×	×	×	..	..	..
Mniaceae									
Mnium cuspidatum Hedw.	×	×	×	×	×	×	×	×	×
Mnium punctatum Hedw.	×	..	..	..	×	×	×	..	×
Mnium rostratum Schrad.	..	×	..	..	..	..	..	..	×

Hypnaceae									
Amblystegiella confervoides (Brid.) Loeske	×	..	×	..	..	..	..	..	..
Amblystegiella subtilis (Hedw.) Loeske	..	..	×	..	..	..	..	..	..
Amblystegium serpens (Hedw.) Bry. Eur.	..	×	..	×	×	..	×	×	×
Amblystegium varium (Hedw.) Lindb.	×	×	×	×	×	×	×	×	×
Brachythecium acutum (Mitt.) Sull.	..	..	..	..	×	..	..	..	..
Brachythecium digastrum C. Müll. & Kindb.	×	×	..	..	..	×	..	..	×
Brachythecium flexicaule Ren. & Card.	..	..	..	..	×	..	..	..	..
Brachythecium oxycladon (Brid.) Jaeger & Sauerb.	×	..	×	..	×	×	×	×	..
Brachythecium plumosum (Sw.) Br. & Sch.	×	..	..	×	..	×	..	..	..
Brachythecium rivulare Bry. Eur.	×	..	..	..	×	..	..	..	..
Brachythecium salebrosum (Web. & Mohr.) Bry. Eur.	×	×	×	..	×	×	×	×	..
Bryhnia graminicolor (Brid.) Grout	×	..	..	..	×	..	..	..	..
Bryhnia novae-angliae (Sull. & Lesq.) Grout	..	..	..	..	..	..	×	..	..
Campylium chrysophyllum (Brid.) Bryhn	×	×	..	×	×	×	×	..	..
Campylium hispidulum (Brid.) Mitt.	..	×	..	..	..	..	×	..	..
Campylium polygamum (Bry. Eur.) Bryhn	×	×	×	×	×	..	..	×	..
Campylium radicale (Beauv.) Grout	..	×	..	..	×	..	..	..	..
Campylium stellatum (Hedw.) Lange & C. Jens.	..	..	..	..	×	..	..	×	..
Chamberlainia acuminata (Hedw.) Grout	×	..	..	×	..	×	..	..	..
Chamberlainia cyrtophylla (Kindb.) Grout	..	×	..	×	..	..	..	×	..
Cirriphyllum boscii (Schwaegr.) Grout	×	×	..	×	×	..	×	..	..
Climaceum americanum Brid.	×	..	..	..	..	..	..	..	..
Drepanocladus aduncus (Hedw.) Warnst.	..	..	..	..	..	..	..	×	..

TABLE I (*continued*)

Musci	South Bass	Middle Bass	North Bass	Gibraltar	Green	Ballast	Rattlesnake	Kelley's	Starve
Hypnaceae—*Continued*									
Entodon cladorrhizans (Hedw.) C. Müll.	..	..	×	..	×	..	..	..	..
Eurhynchium hians (Hedw.) Jaeger & Sauerb.	×	×	×	×	×	×	×	×	×
Eurhynchium rusciforme (Neck.) Milde	×	..	..	..	..	..	..	..	..
Eurhynchium serrulatum (Hedw.) Kindb.	×	..	×	..	×	..	..	×	..
Homomallium adnatum (Hedw.) Broth.	×	×	×	..	..	..	×	×	..
Hygroamblystegium fluviatile (Hedw.) Loeske	×	×	×	×	×	×	×	×	×
Hygroamblystegium irriguum (Wils.) Loeske	×	×	×	×	×	..	×	×	×
Hygroamblystegium irriguum var. spinifolium (Schimp.) Grout	×	×	..	..	..	..	..	..	..
Hygrohypnum eugyrium (Bry. Eur.) Loeske	×	..	..	×	×	..	..	..	..
Hygrohypnum palustre (Hedw.) Loeske	×	×	..	×	×	×	×	×	..
Hypnum curvifolium Hedw.	..	..	..	..	×	..	×	..	..
Leptodictyum riparium (Hedw.) Warnst.	×	×	×	..	×	..	..	×	..
Leptodictyum trichopodium (Schultz) Warnst.	..	×	×	×	..	×	..	×	..
Leptodictyum trichopodium var. kochii (Bry. Eur.) Broth.	×	..	×	..	×	..	..	×	..
Plagiothecium denticulatum (Hedw.) Bry. Eur.	×	×	..	..	×	..	..	..	×

Plagiothecium deplanatum (Sull.) Grout	×	..	..	..	..	..	..	..	..
Plagiothecium geophilum (Aust.) Grout	..	..	..	..	×	..	..	..	..
Plagiothecium pulchellum (Hedw.) Bry. Eur.	..	..	..	..	×	..	..	..	..
Plagiothecium sylvaticum (Brid.) Bry. Eur.	..	×	..	..	..	..	..	×	..
Rhytidiadelphus triquetrus (Hedw.) Warnst.	×	..	..	..	..	..	..	..	..
Leskeaceae									
Anomodon attenuatus (Hedw.) Hüben	×	..	×	..	×	×	×	..	..
Anomodon minor (Beauv.) Lindb.	..	×	..	×	..	×	×	×	..
Anomodon rostratus (Hedw.) Schimp.	×	..	×	×	×	×	×	×	..
Anomodon rugelii (C. Müll.) Keissl.	..	..	..	..	×	×	..	..	..
Leskea nervosa (Schwaegr.) Myrin.	×	..	..	..	..	..	..	..	..
Leucodontaceae									
Leucodon sciuroides (Hedw.) Schwaegr.	..	..	..	×	..	..	..	..	..
Moss total	70	44	33	50	60	35	43	54	30
Hepaticae									
Cephaloziaceae									
Cephalozia catenulata (Hüben) Spruce	×	..	..	..	..	..	..	..	..
Harpanthaceae									
Chiloscyphus pallescens (Ehrh.) Dumort.	..	..	..	..	..	..	×	..	..
Jungermanniaceae									
Lophozia sp.	..	..	..	..	..	×	..	..	..
Porellaceae									
Porella platyphylla (L.) Lindb.	×	..	..	..	..	..	..	..	..
Porella platyphylloidea (Schwein.) Lindb.	..	..	..	×	..	..	×	..	..

TABLE I (*continued*)

Hepaticae	South Bass	Middle Bass	North Bass	Gibraltar	Green	Ballast	Rattlesnake	Kelley's	Starve
Lejeuneaceae									
Cololejeunea biddlecomiae (Aust.) Evans	×	..	..	..	..	..	..	..	..
Marchantiaceae									
Marchantia polymorpha L.	..	..	..	..	×	..	×	..	..
Preissia quadrata (Scop.) Nees	×	..	..	..	×	..	..	×	..
Conocephalum conicum (L.) Dumort.	×	×	..	×	×	..	×	×	..
Rebouliaceae									
Reboulia hemisphaerica (L.) Raddi.	..	..	..	..	×	..	×	×	..
Ricciaceae									
Ricciocarpus natans (L.) Corda	..	..	×	..	..	..	..	×	..
Riccia fluitans L.	..	×	×	..	..	..	..	×	..
Hepatic total	5	2	2	2	4	1	5	5	0
Grand total	75	46	35	52	64	36	48	59	30

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STUDIES ON THE GENUS INOCYBE

II. NEW AND NOTEWORTHY SPECIES FROM MICHIGAN

DANIEL E. STUNTZ

IN THE summer months of 1947 and 1949 I had the opportunity of collecting fleshy fungi during two sessions of the University of Michigan Biological Station at Douglas Lake, Michigan, in the company of Dr. Alexander H. Smith and, in 1947, of Morten Lange. A number of localities in Emmet and Cheboygan counties were visited repeatedly during both seasons, and in 1949 trips were made to Tahquamenon State Park and to the shore of Lake Michigan northwest of St. Ignace. The wide range of terrain and vegetation in these areas was reflected in an abundant and varied fungous flora. One of the features of this flora of considerable interest to Dr. Smith and myself was the occurrence of several fungi we had come to look upon as typically western in distribution, frequently in a habitat (under hardwoods) quite different from the coniferous forests in which we had been accustomed to finding them. Three such instances are cited in this paper.

The eighteen members of Inocybe described in the following pages represent a relatively small part of the total number of species of that genus that were found. Indeed, the two seasons' collecting indicated very clearly that in northern Michigan alone there is an Inocybe flora which is far from being fully explored. As the same situation doubtless exists in many other regions of North America, one may well wonder what portion of the number of species of Inocybe actually present in this continent has thus far been revealed.

I should like to express here my sincere thanks to Dr. A. H. Stockard, director of the Biological Station, as well as to the members of his staff, for many kindnesses which made working at the station a pleasure. To Dr. Alexander H. Smith, who made every effort to ensure the success of our two seasons' collecting, I am especially indebted. The citation of collections will show how substantially he contributed to the material upon which this paper is based.

In the descriptions which follow, color terms taken from Ridgway (1912) are indicated by quotation marks, and those taken from Maerz and Paul (1930) are designated by a combination of numerals and a capital letter (e.g., centennial brown 14K9). Portions of certain of the collections have been deposited in the Herbarium of the University of Michigan, at Ann Arbor, Michigan; the remainder are in the Herbarium of the University of Washington, at Seattle, Washington.

Description of Species

Inocybe armoricana Heim, Le Genre Inocybe, p. 295. 1931

Var. *armoricana*

Habitat.—Single to gregarious, on the ground in humus in stands of mixed hardwoods, July through September.

Material studied.—Stz. 5421, coll. A. H. Smith, Mackinaw City, Mich., July 31, 1949; two unnumbered collections by Paul Harding, Mackinaw City, Aug. 7, 1949; Stz. 5489, Upper Tahquamenon Falls, Mich., Sept. 2, 1949; Stz. 5534, 5536, 5560, 5564, 5565, coll. A. H. Smith, same locality as the preceding, Sept. 6, 1949; Stz. 5614, same locality as the preceding, Sept. 11, 1949; Stz. 5818, coll. A. H. Smith, Wilderness Point State Park, Mich., Sept. 24, 1949.

Observations.—A description of this variety, drawn from specimens collected in Mt. Rainier National Park, Washington, was given in a previous paper (Smith and Stuntz, 1950, p. 89) and need not be repeated here. In some of the collections cited above, the spores are slightly larger than those of the plants from Washington (8–11.5 μ long, as compared with 8–10 μ for most of the western material), and in most instances the aromatic component of the odor is more pronounced in the eastern plants. Except for such minor and inconstant differences as these, however, the specimens from these two widely separated areas are alike.

The extension of the known range of this variety of Inocybe from Washington to Michigan, coupled with the fact that it appears to be rather common in both regions, causes one to suspect that it is actually widely distributed in the United States. Perhaps it has been confused with *I. fastigiata* (Fr.) Quél., which it resembles in appearance, and one might therefore find it under that name in various herbaria.

Var. **phaeoderma**, var. nov.

(Pl. I, Figs. 1–2; Pl. III)

A typo pilei colore umbrino differt.

Pileus 3–4.5 cm. broad, at first conic-campanulate, becoming expanded with a large conic-mammiform umbo, the margin gently rounded to plane; surface smooth, innately silky, subshining, remaining unbroken at the center, becoming rimose toward the margin; color "auburn" or "chestnut brown" or "russet," usually somewhat paler at the margin; context firm, pallid, unchanging on exposure, odor a mixture of green-corn and sweetish aromatic components, or sometimes with an added spermatic component, or occasionally merely aromatic, without the green-corn component. Lamellae adnate, broadly rounded at the stipe, bluntly pointed at the margin, oblong-subventricose, not broad (4–5 mm. wide), moderately close; color at first pallid (ivory 10B2), becoming pale dingy buff (11C3), finally darker and decidedly olivaceous (14I7). Stipe 5–7 cm. long, 5 mm. thick, terete or somewhat compressed, equal, the base usually with a flat, round-margined bulb 10–11 mm. broad; solid, the context pallid, unchanging on exposure; surface satiny, glabrous, conspicuously longitudinally hygrophanous-striate; color pallid (cream 9D2, vanilla 10C3), becoming flushed and spotted with "rufous" or "hazel" or "cinnamon," finally more or less uniformly some shade of dingy brownish buff (11F7, 12C7, 13E8), mottled with darker brown ("Verona brown").

Spores 8–11 × 4.5–5.5 μ, mostly 9–10 × 5 μ, subreniform; pleurocystidia lacking; cheilocystidia abundant, densely clustered along the edge of the lamella, 35–60 × 14–25 μ, clavate to ventricose with broadly rounded apex, thin-walled, hyaline; basidia 30–34 × 7–11 μ, clavate, four-spored; surface of the pileus a thin, compact layer of parallel, radially arranged, slender, cylindrical hyphae 7–9 μ in diameter, with pale brown walls bearing faint banded incrustations, and with clamp connections at nearly every septum.

Habitat.—Single to gregarious, on the ground in humus in stands of mixed hardwoods, in the fall. Collected thus far only in a small area near Upper Tahquamenon Falls.

Material studied.—Stz. 5535 (TYPE), 5547, 5561, 5566, coll. A. H. Smith and D. E. Stuntz, Upper Tahquamenon Falls, Mich., Sept. 6,

1949; Stz. 5602, 5606, 5608, same locality as the preceding, Sept. 11, 1949.

Observations.—Just as *Inocybe armoricana* var. *armoricana* probably has been confused with *I. fastigiata*, so the variety *phaeoderma* may have been identified as either *I. fastigiella* Atk. or *I. umbrinella* Bres., both of which it resembles very closely. However, its characteristic odor should enable one to distinguish fresh specimens of it readily from both the other species of Inocybe mentioned, and dried specimens should be identifiable by their spores, which are intermediate in size between those of *I. fastigiella* and those of *I. umbrinella.*

The principal difference between var. *armoricana* and var. *phaeoderma* lies in the color of the pileus; this appears to be quite constant, however, and I have yet to see any specimens which could not readily be referred, because of an intermediate coloration, to one variety or the other. The odor of var. *phaeoderma* seems to be more variable than that of var. *armoricana*, especially in the occasional lack of the green-corn component. Its sweetish aromatic component is very like the odor of bruised geranium leaves.

Inocybe cervicolor (Pers.) Karsten, sensu Konrad and Maublanc, Icones Selectae Fungorum, Vol. 1, pl. 88. 1928

(Pl. I, Figs. 3–4)

Pileus 1.5–4.5 cm. broad, at first campanulate and umbonate, becoming expanded with a broad umbo and broadly rounded margin, the margin finally plane; surface from the first fibrillose-squamose, with rather conspicuous, somewhat coarse scales which are recurved on the disc and appressed toward the margin, the margin itself merely lacerate-fibrillose; scales "russet" (fading eventually to near "Mikado brown" or "Verona brown") on a paler, dingy, straw-colored ground color ("pinkish buff" or 11D5, 11E5, darkening to 12C6 or 12E6); context firm, compact, white to pallid buff, slowly (and sometimes faintly) rubescent where exposed, odor very strong and persistent, of green corn. Lamellae adnate, broadly to deeply and abruptly rounded at the stipe, pointed at the margin, ventricose, moderately broad (3.5–8 mm. wide), moderately close, from 40 to 50 reaching the stipe, with one series of shorter ones inserted; color at first white, becoming sordid buff (12D5), finally brownish olivaceous ("Dresden brown" or 14J8 or 14K9), with conspicuously pallid edges.

Stipe 4–7.5 cm. long, 2.5–7 mm. thick, terete or somewhat compressed, equal, the base not bulbous; solid, or sometimes becoming hollow entirely or in part, context pallid or pale buff, slowly becoming reddish where cut or exposed, darkening to tawny or vinaceous brown in older specimens; surface at first longitudinally fibrillose-streaked, remaining sparsely so toward the base, elsewhere becoming satiny-fibrous and subshining and longitudinally striate, the apex sparsely punctate; color at first entirely white to "cartridge buff," then becoming flushed from the base upward with reddish cinnamon, finally the upper portion "cinnamon buff" or darker (13E8 to 13D7), shading into "tawny" or "russet" at the base.

Spores 11–16 × 6–7.5 μ, inequilaterally elongate-amygdaliform; pleurocystidia lacking; cheilocystidia 50–105 × 10–16.5 μ, clavate or subventricose with sinuous edges, hyaline, densely crowded along the edge of the gills; basidia 45–54 × 9–11.5 μ, four-spored; surface of the pileus a compact layer of parallel to somewhat interwoven hyphae with cylindrical to slightly ventricose cells 9–14 μ in diameter, with pale to rather dark brown walls which are usually faintly banded, and with clamp connections at the septa; numerous lactifers present in the trama of the pileus.

Habitat.—Single to gregarious, on the ground in humus in stands of mixed hardwoods and in a stand consisting principally of maples and hemlock, July.

Material studied.—Stz. 2913, along the road from Harbor Springs to Cross Village, Emmet Co., Mich., July 20, 1947; Stz. 2978, coll. A. H. Smith, same locality as the preceding, July 23, 1947; Stz. 5094, same locality as the preceding, July 5, 1949.

Observations.—This species of Inocybe has not been reported previously from North America. The species name is used here in the sense of Konrad and Maublanc, with whose description and illustration the cited specimens agree very well. Lange (1938, p. 80) and Heim (1931, p. 389) consider *I. cervicolor* to be a variety of *I. bongardi* (Weinm.) Quél., but unless I come upon specimens with the type of odor described by Heim (1931, pp. 310–311) for *I. cervicolor*, I shall continue to regard it as an autonomous species. The brown, scaly pileus, rubescent context, large spores, and, especially, the strong odor of green corn, offer a combination of characteristics that makes this an easy species to identify.

It should be mentioned that *Inocybe subrubescens* Atk. apparently

is a very closely related species. The principal macroscopic feature wherein it differs from *I. cervicolor* would seem to be the color of the pileus, which in *I. subrubescens* is said to be "dull-ochraceous, becoming suffused with a reddish color" (Kauffman, 1924, p. 256). I have examined the type of *I. subrubescens* and can state that its microscopic characteristics are essentially the same as those of *I. cervicolor*. Unfortunately, in his description (1918, p. 216) Atkinson did not say anything about the odor of *I. subrubescens*, nor could I find any mention of it on the label which accompanies the type specimens; hence the two species cannot be compared directly with regard to this important point.

Inocybe cryptocystis, sp. nov.

(Pl. I, Figs. 5–7; Pl. IV)

Pileus 1–2.5 cm. latus, campanulato-expansus, saepe umbonatus, siccus, sericeo-fibrillosus, levis vel ad marginem leviter rimosulus, luteus vel stramineus; caro pallida, immutabilis, odor farinaceo-spermaticus; lamellae adnexae vel anguste adnatae, ventricosae, 3–4 mm. latae, ex albis griseo-olivaceae; stipes 2–4.5 cm. longus, 2–4 mm. crassus, aequalis, basi bulbosus et submarginatus, sursum albo-pruinatus, deorsum leviter fibrillosus demum glabrescens, longitudinaliter striatus, luteus vel stramineus; sporae 6.5–10 (11) × 5–6.5 μ, leves, amygdaliformes; pleurocystidia 24–35 × 8–12 μ, cylindraceo-subventricosa, ex hymenio vix prominentia.

Pileus 1–2.5 cm. in diameter, most frequently 1.5–2 cm., sometimes up to 3.5 cm., campanulate, becoming expanded and broadly campanulate, finally plane or almost so, with or without a rounded umbo, the margin long remaining broadly rounded, finally plane; surface smooth, dry, innately silky or appressed-fibrillose, lubricous when wet, remaining smooth on the disc and usually elsewhere also, but sometimes becoming finely rimose toward the margin, or occasionally even excoriated or diffracted-squamulose between the center and the margin; color more or less uniformly some shade of yellow or yellow buff, such as "chamois," "honey yellow," "antimony yellow," 10H4, 11J6, or 11K7, the disc in some a paler shade ("cream buff"), and in others the margin becoming brassy yellow (11L7, 12K8); context 1.5–2 mm. thick at edge of the disc, white or pallid, firm, unchanging on exposure, odor a mixture of spermatic and farinaceous, usually

rather strong and disagreeable, sometimes merely farinaceous and rather faint. Lamellae adnexed to narrowly adnate, abruptly and broadly rounded at the stipe, bluntly pointed to bluntly rounded at the margin, ventricose, rather broad (3–4 mm. wide), moderately close; color at first white to pallid (9C2 or ivory 10B2), becoming pale grayish olivaceous (11F5 to 12C4), finally darker grayish olivaceous (Arizona 13E6, khaki 13J7). Stipe 2–4.5 cm. long, 2–4 mm. thick, terete, equal, the base with a flattened to napiform bulb (4–7 mm. broad) with a rounded submarginate edge; solid, the context white to pallid, unchanging on exposure, but becoming darker yellowish to buff in age; surface densely and finely white- or pallid-pruinate in the upper third, elsewhere minutely silky-fibrillose-streaked, remaining pruinate above, elsewhere glabrescent and rather notably longitudinally hygrophanous-striate; color at first entirely pallid yellow ("ivory yellow"), then pallid at the apex, and elsewhere some shade of yellow or yellow buff ("cream buff," "chamois," maize 10G5, 11K6, 12K6, or as dark as 12L8 or 13L8 at the base), or becoming yellow all over.

Spores 6.5–10 (11) × 5–6.5 μ, mostly 8–9 × 5.5 μ, inequilaterally amygdaliform, with bluntly pointed apex; pleurocystidia 24–35 (40) × 8–12 (18) μ, mostly 31.5 × 10 μ, not or scarcely projecting above the surface of the hymenium, ventricose-subcylindric to clavate, the base usually broad and apedicellate, but sometimes narrowed to a slender pedicel, the apex obtuse, the wall varying from uniformly thin to definitely thickened in the upper half or third; cheilocystidia of two kinds, most of them like the pleurocystidia in size and shape, but a few vesiculose to short-clavate, about 20–34 × 10–18 μ; basidia short-clavate, 20–30 × 8–12 μ, four-spored; lamellar trama parallel, composed of compactly arranged, short, cylindric-subventricose cells, about 20–45 × 11–18 μ; surface of the pileus a very compact layer, about 40–50 μ thick, of slender parallel hyphae 2.5–5.5 μ in diameter, with yellowish-brown, slightly roughened walls, and with occasional clamp connections at the septa; the hyphae at the surface sometimes gelatinizing slightly, but not forming a true gelatinous layer; no lactifers seen in any of the tissues.

Habitat.—Single to gregarious, on the ground in rich humus in stands of mixed hardwoods, June and July.

Material studied.—Stz. 846, coll. A. H. Smith, Ann Arbor, Mich., June 28, 1940; Stz. 874, Milford, Mich., July 2, 1940; Stz. 3001,

woods near Harbor Springs, Mich., July 23, 1947; Stz. 5149, woods near Mackinaw City, Mich., July 11, 1949; Stz. 5151, woods near French Lake, Emmet Co., Mich., July 11, 1949; Stz. 5157, coll. A. H. Smith, woods near Mackinaw City, July 11, 1949; Stz. 5366, woods below Old Lighthouse, Mackinaw City, July 26, 1949; Stz. 5400 (TYPE), same locality as the preceding, July 29, 1949; Stz. 5417, coll. A. H. Smith, woods near Mackinaw City, July 30, 1949.

Observations.—The very short pleurocystidia, which rarely project any appreciable distance above the level of the hymenium, are the principal distinctive characteristic of this species of Inocybe. Other noteworthy features are the small size, the uniformly yellow or yellow-buff pileus without fulvous or tawny shades, the submarginately bulbed yellow stipe, and the farinaceous-spermatic odor.

Inocybe cryptocystis belongs in a small group of rather similar species comprising, in addition, *I. hirtella* var. *paupera* Möller, *I. langei* Heim, *I. connexa* Kauffm., and the species which Heim (1931, p. 333) calls *I. confusa* Karst. All four of these have pleurocystidia which are larger than those of *I. cryptocystis* and which project above the general level of the hymenium. *I. hirtella* var. *paupera* differs further in having larger spores, a darker pileus, and a stipe with a rounded rather than a submarginate bulb. *I. langei* has smaller spores, a fibrillose-squamulose pileus which is usually definitely tawny or fulvous at the center, and an entirely white stipe. *I. connexa* and *I. confusa* sensu Heim appear to be the species most closely related to *I. cryptocystis*. *I. cryptocystis* has in common with *I. connexa* the yellow pileus color, an odor with a farinaceous component, and its spore size, and differs in its smaller pleurocystidia, in the stipe's being yellow instead of white, and in the smaller size of the carpophores. *I. confusa* sensu Heim has pleurocystidia which are the closest in size to those of *I. cryptocystis* of any of the other species mentioned, but which are nonetheless appreciably larger, averaging about 40 μ in length. There is likewise a difference in odor between the two species, that of *I. confusa* being at most faintly spermatic, with no farinaceous component. In other particulars, to judge from Heim's description, there is considerable similarity between the two plants. I might add, however, that *I. cryptocystis* does not particularly resemble either of the two somewhat different-looking plants figured by Heim (1931, pl. XVIII, figs. 1–2) under the name of *I. confusa*.

Inocybe descissa (Fr.) Quél. var. *macrospora* Heim, Le Genre Inocybe, p. 235. 1931

(Pl. I, Figs. 8–9)

Pileus 2 cm. broad, persistently conic-campanulate, with a low umbo; surface smooth, appressed-fibrillose, unbroken at the center, a little rimose toward the margin; color uniformly "tawny olive"; context thin (1.5 mm. thick at edge of disc), firm, white, unchanging on exposure, odor faintly spermatic. Lamellae adnate, rounded-sinuate at the stipe, bluntly pointed at the margin, ventricose, broad (4 mm. wide), rather thick and rigid, subdistant, about 32 reaching the stipe, with an incomplete series of shorter ones irregularly inserted; color about "tawny olive." Stipe 5 cm. long, 3 mm. thick, terete, equal; broadly hollow, the context white within, with a thin, rigid, pinkish-buff surface layer; surface glabrous and satiny, shining, only the apex sparsely white-pruinate; color "pinkish buff," with a flush of "pinkish cinnamon" at the apex.

Spores 9–12.5 (13.5) × 5.5–6 μ, inequilateral-amygdaliform; pleurocystidia 60–72 × 12–18 μ, ventricose, with a short pedicel and a long, tapering neck, thick-walled, hyaline in KOH; cheilocystidia of two kinds, some the same size and shape as the pleurocystidia, others short-clavate, hyaline, thin-walled, about 22–34 × 11–16 μ; basidia 30–34 × 8–11 μ, four-spored; pileus surface a compact layer of radially oriented parallel hyphae 7–16 μ in diameter, with thin brown walls having banded incrustations, and with occasional clamp connections at the septa.

Habitat.—Single, on the ground in a boggy area in a stand of mixed hardwoods and conifers.

Material studied.—Stz. 5012, coll. A. H. Smith, Rees's Bog, Burt Lake, Mich., June 28, 1949.

Observations.—The description above is drawn from a single collection, and hence does not convey any idea of the possible variability of color, size, and the like. It corresponds very well, however, to the account given by Heim (*op. cit.*) of his variety *macrospora*, so I consider that the presence in North America of this variety of *Inocybe descissa* is established. It remains to be seen whether or not its apparent rarity was merely an accident of collecting. One should be able to recognize it readily by its smooth, umbrinous pileus, by its pallid, hollow stipe, and by the size of its spores.

Inocybe godeyi Gill., sensu Josserand and Kühner, Bull. Mens. Soc. Linn. de Lyon, 17: 86. 1948

(Pl. I, Figs. 10–11)

Pileus 2–4 cm. in diameter, broadly campanulate, becoming expanded-campanulate, scarcely at all umbonate, the margin gently rounded, soon becoming plane, even, and entire; surface smooth, innately silky, subglabrous, dull, remaining unbroken even in age; color at first dingy buff (11I6, 12H6), becoming darker buff (12I7, 12J7), from the first flushed with bright rufous, soon becoming mottled with rufous or reddish ferruginous ("rufous," "ferruginous," "apricot orange," 12A10, 11A4, 11B4, and so on), and eventually becoming entirely red; context moderately thick, firm, pallid, unchanging on exposure, odor spermatic, strong, disagreeable. Lamellae broadly adnate, very shallowly depressed at the stipe or not at all so, bluntly pointed at the margin, subventricose, not broad (3–4 mm. wide), moderately close, with many short ones inserted in various lengths; color at first pallid (9C1), becoming grayish straw color (12E5), finally olivaceous (14I6), soon spotted and stained with "vinaceous rufous" or "Hay's russet." Stipe 2.5–6 cm. long, 4–5.5 mm. thick, terete, equal, the base with a conspicuous flat-margined bulb 7–11 mm. broad; solid, the context pallid or flushed here and there with salmon incarnate or geranium pink, or in some entirely pink, unchanging on exposure; surface densely pallid-pruinate all over, conspicuously longitudinally hygrophanous-striate, eventually more or less glabrescent and satiny; color at first pallid (9C1), soon becoming flushed with shades of red ("rufous," "flesh ochre," "apricot buff," "apricot orange," 11A10, 11B10), eventually becoming entirely "carnelian red" to "carrot red."

Spores 9–12 (13.5) × 5–6–7 μ, inequilateral-amygdaliform, the dorsal profile with both a suprahilar depression and a median to subapical hump, giving the spores a characteristic outline in lateral view; pleurocystidia 45–75 × 18–27 μ, ventricose to ventricose-subclavate, with a narrow pedicel, varying from thin-walled to definitely thick-walled, hyaline or tinged brown in KOH; cheilocystidia of two kinds, some like the pleurocystidia in size and shape, others short-clavate to oval, thin-walled, hyaline, 22–34 × 13–20 μ; basidia 27–32 × 7–9 μ, four-spored; surface of the pileus consisting of two thin layers of appressed, radially arranged hyphae, the outermost

layer seven or eight cells deep, composed of slender, hyaline, rather thick-walled hyphae 2.5–6.5 μ in diameter, with numerous clamp connections, parallel or slightly and rather loosely interwoven, and the subjacent layer consisting of a few strands of very compactly arranged, slender, colored hyphae with faintly encrusted walls, with which are intermingled a few of the broader (13–16 μ in diameter) subfusiform cells of the underlying pileus trama.

Habitat.—Gregarious, on the ground in humus under conifers, September.

Material studied.—Stz. 5677 and 5678, both coll. A. H. Smith, Wilderness Point State Park, Mich., Sept. 14, 1949.

Observations.—Josserand and Kühner (*op. cit.*), in clearly defining a species of Inocybe to which the name *I. godeyi* Gill. may be applied, have helped greatly to clear up a mycological puzzle which was very annoying to those of us who have had to deal with it, as it were, "from a distance." Whatever one may think about the reasons advanced by these authors for maintaining Gillet's specific epithet in preference to the name *I. rickeni* Kallenbach, it is earnestly to be hoped that their solution of the problem of the identity of *I. godeyi* will find general acceptance, and that at least that aspect of the question can be considered settled.

As Josserand and Kühner point out, *Inocybe godeyi* is easily distinguished from the species which they call *I. pudica* Kühner, especially by its entirely pruinate stipe with an evident marginate bulb, but also by its larger and differently shaped spores as well as by the general outline of its sporocarp.

Inocybe griseo-lilacina Lange, Dansk Botanisk Arkiv, Bd. 2, No. 7, p. 33. 1917

Pileus 1–2.5 cm. broad, broadly campanulate, umbonate, densely and coarsely fibrillose, diffracted-squamulose at the center, excoriate-rimose at the margin; color pallid grayish drab with an obscure lilac tinge, about "avellaneous" to "vinaceous buff." Lamellae adnate, shallowly rounded at stipe and margin, subventricose, not broad (2–3 mm. wide), moderately close; color olivaceous. Stipe 4.5–6.5 cm. long, 3–3.5 mm. thick, terete, equal; solid, the context lilac; surface satiny, conspicuously shagreened or streaked with a copious layer of pallid superficial fibrils; color lilac to "vinaceous fawn," appearing paler because of the surface fibrils.

Spores 7–9.5 × 5–5.5 μ, inequilaterally amygdaliform; pleurocystidia 45–50 × 11–14 μ, ventricose to cylindric-subventricose above a slender pedicel of varying length, moderately thick-walled.

Habitat.—Solitary, on the ground in humus under hardwoods or in stands of mixed hardwoods and conifers, June and July.

Material studied.—Stz. 5024, coll. Paul Harding, Wolf's Bog, Cheboygan Co., Mich., June 29, 1949; Stz. 5202, coll. A. H. Smith, Munro Lake, Cheboygan Co., July 13, 1949.

Observations.—The brief description above is intended to supplement that given elsewhere (Smith and Stuntz, 1950, p. 93) of specimens collected in Mt. Rainier National Park, Washington. The plants from Michigan resemble Lange's illustration (1938, pl. 111, fig. F) of *Inocybe griseo-lilacina* more closely than do those of the western collections, in that they are more slender, with the stipe longer in proportion to its thickness, just as Lange shows it. In other respects the eastern and western specimens are alike. This is the first report of *I. griseo-lilacina* from the eastern United States.

Inocybe intricata Peck, Bull. New York State Mus., 131: 36. 1909

(Pl. I, Figs. 12–13)

Pileus 1–2.5 cm. broad, campanulate to conic-campanulate, becoming expanded, with prominent umbo and shallowly rounded to plane margin; surface smooth, dry, innately silky and shining, remaining unbroken on the disc, becoming conspicuously long-rimose toward the margin, sometimes more or less diffracted-subscaly in age; color uniformly "ochraceous tawny" to spruce yellow 12K8, or darker reddish brown ("auburn," "amber brown") at the center and "buckthorn brown" to mummy 14J9 at the margin; context thin (1 mm. thick at edge of disc), pallid or pale yellow, unchanging on exposure, odorless or with just a trace of raphanoid odor. Lamellae adnexed, almost free in some specimens, tapering toward the stipe, bluntly pointed at the margin, oblong-subventricose, widest nearer the margin, moderately close; color "cinnamon buff," becoming olivaceous (mummy 14J9). Stipe 2.5–5 cm. long, 1.5–3.5 mm. thick, terete, equal above the base, which has a conspicuous flat-margined bulb 4–5 mm. in diameter; solid, the context pallid to pale watery

brown, unchanging on exposure but tending to darken slowly with age; surface everywhere densely and conspicuously pruinate, satiny and shining underneath the pruina; color at first ivory or pallid, becoming dingy yellowish (walnut 12E6), finally brassy yellowish brown (13K8) to tawny ochre (hazel 13J9).

Spores 9–12 × 8–9 μ, oblong to oval, with from 10 to 12 large, coarse, subconic nodules; pleurocystidia 60–78 × 14–20 μ, ventricose above a short pedicel, with a cylindric or tapering neck, decidedly thick-walled, hyaline to pale yellowish brown in KOH; cheilocystidia mostly of the same size and shape as the pleurocystidia, but some short, clavate, thin-walled ones present also; basidia 28–34 × 7–11.5 μ, four-spored; surface of the pileus a rather thick layer of very compactly arranged, cylindrical, parallel, radially oriented hyphae 8–14 μ in diameter, with conspicuous banded incrustations of yellowish-brown pigment, and with numerous clamp connections at the septa; lactifers fairly abundant in the pileus trama.

Habitat.—Solitary or in groups of three or four individuals, on moist ground in swampy places in stands of mixed conifers and hardwoods, July.

Material studied.—Stz. 2801, middle bridge, Maple River Valley, Emmet Co., Mich., July 14, 1947; Stz. 2822, 2827, coll. A. H. Smith, M. Lange, and D. E. Stuntz, same locality as the preceding, July 15, 1947; Stz. 2848, coll. A. H. Smith, Wolf's Bog, Cheboygan Co., Mich., July 16, 1947.

Observations.—*Inocybe intricata* has much the appearance of a miniature *I. asterospora* Quél.—a fact that Kauffman apparently recognized, to judge from the juxtaposition of the two species in his monograph (1924, p. 228). However, in addition to being much smaller than *I. asterospora*, *I. intricata* has a differently colored stipe (yellow-brown rather than reddish brown or russet) and differently shaped spores. The illustration given by Lange (1938, pl. 115, fig. B) of the plant he calls *I. xanthomelas* Boursier & Kühner could equally well represent my collections of *I. intricata*. I am rather inclined to believe, in fact, that it actually does represent *I. intricata* rather than *I. xanthomelas*, the more so since Lange's description (1938, p. 84; also 1917, p. 43) leaves considerable doubt as to whether the stipe of his specimens showed the blackening during drying that is so characteristic of *I. xanthomelas*.

Inocybe leiocephala Stuntz, Mycologia, 42: 98. 1950

Habitat.—On the ground in humus in stands of mixed hardwoods.

Material studied.—Stz. 2983, coll. M. Lange, A. H. Smith, and D. E. Stuntz, Harbor Springs, Mich., July 23, 1947; Stz. 5674, Weimar Lake, Emmet Co., Mich., Sept. 14, 1949; Stz. 5693, coll. A. H. Smith, Miller's Bog, Burt Lake, Mich., Sept. 17, 1949.

Observations.—This species was described recently (Smith and Stuntz, 1950, p. 98) from collections made in Mt. Rainier National Park, Washington. The establishment of its presence in Michigan, in a habitat very different from that (coniferous forests) which it normally occupies in Washington, leads one to suspect that it may be widely distributed in the northern United States. There seems to be no difference between the eastern and the western plants; in the former, as in the latter, the characteristic glabrous, hygrophanous-subcartilaginous cuticle of the pileus furnishes the principal feature for recognition of the species in the field. If this feature were overlooked, the collection would very likely be referred to *Inocybe subdestricta* Kauffm.

Inocybe leptocystis Atkinson, Am. Journ. Bot., 5: 212. 1918

(Pl. I, Figs. 14–15)

Pileus 1–5 cm. broad, campanulate, becoming expanded and shallowly convex to plane, usually with a low, broad umbo, and the margin shallowly arched; surface at first with a thin, webby layer of pallid superficial fibrils which eventually disappear, revealing the cuticle; cuticle innately silky, smooth at first, soon becoming imbricately furfuraceous-squamulose everywhere except on the umbo, the squamules small, flat and appressed to partly recurved; color some shade of red-brown or russet, such as "Mars brown," "russet," "cinnamon brown," "bay," "auburn," cocoa 7E12, Mohawk 7H12, and the like, sometimes fading to "tawny" at the center and "tawny olive" on the margin, infrequently with a pallid zone ("avellaneous," tansan 12B6) at the margin; context 1–2 mm. thick at edge of disc, firm, white, unchanging on exposure, odor faint, raphanoid with saponaceous or farinaceous components, varying with different collections. Lamellae adnexed to adnate, shallowly to deeply and abruptly rounded at the stipe, pointed at the margin, subventricose, not broad (2.5–4 mm. wide), rather close; color white at first, becoming grayish

buff (12C5), then grayish olivaceous (13K7), finally rather dark olivaceous (antique bronze 14L10). Stipe 2.5–7.5 cm. long, 1.5–6 mm. thick, terete, equal or occasionally a little incrassated downward, sometimes flexuous, the base not bulbous, or at most with a slight oval bulb; solid, the context pallid with more or less of a slight incarnate tinge, unchanging on exposure, usually fading to yellowish in age; surface at first sparsely silky-fibrillose, soon becoming glabrous and satiny-shining, finely longitudinally striolate, with the apex sparsely white-pruinate; color pallid at first, then definitely incarnate or salmon incarnate ("pinkish cinnamon," "vinaceous cinnamon," Dorado 11C6, cork 12B7, bran 12D7), usually fading in age to "pinkish buff" or "warm buff," the apex and base frequently pallid; very infrequently the color not the incarnate colors indicated, but a shade of pale watery brown.

Spores 7–10 × 5–6 μ, smooth, inequilateral-amygdaliform, with shallowly convex dorsal profile and broadly rounded ventral profile; pleurocystidia 45–60 × 12–19 μ, ventricose to cylindric-subventricose, always with a broad, obtusely rounded, subcapitate to definitely capitate apex, which is frequently surmounted with a broad globular cap of amorphous gelatinous material, definitely *thin-walled*, with only the apex of some having a slight meniscus-like thickening; cheilocystidia of two kinds, one resembling the pleurocystidia in size and shape and wall thickness, and almost always having a globular amorphous cap, the other short, clavate to inflated-clavate, 22–45 × 11–22 μ; basidia 18–25 × 7–9 μ, four-spored; surface of the pileus a rather deep layer of radially oriented parallel hyphae which are a mixture of narrow cylindric ones and ones with broader and more ventricose or inflated cells, varying from 7 μ to 18 μ in diameter, all with irregular incrustations of red-brown pigment, with clamp connections present but not numerous.

Habitat.—Single to rather densely gregarious, on the ground in humus and among mosses, often in swampy areas, in stands of mixed hardwoods and in mixed stands of conifers and hardwoods, June and July.

Material studied.—Lange 918, Stz. 2424, coll. M. Lange, Rees's Bog, Burt Lake, Mich., June 23, 1947; Stz. 2377, coll. M. Lange and D. E. Stuntz, same locality as the preceding, June 28, 1947; Stz. 2522, 2526, Wolf's Bog, Cheboygan Co., Mich., June 30, 1947; Stz. 2553, coll. M. Lange, Rees's Bog, Burt Lake, July 3, 1947; Stz. 2619,

2620, 2621 (= Sm. 25520), 2622, lower bridge, Maple River Valley, Emmet Co., Mich., July 6, 1947; Stz. 2697, "the Gorge," Univ. Mich. Biol. Sta., Cheboygan Co., July 10, 1947; Stz. 2711, coll. M. and B. Lange, same locality as the preceding, July 11, 1947; Stz. 2732, coll. A. H. Smith, Rees's Bog, Burt Lake, July 12, 1947; Stz. 2746, same locality as the preceding, July 13, 1947; Stz. 2757, middle bridge, Maple River Valley, Emmet Co., July 13, 1947; Stz. 2837, "the Gorge," Univ. Mich. Biol. Sta., July 17, 1947; Stz. 2975, Harbor Springs, Mich., July 23, 1947; Stz. 5069, 5070, coll. Frances Boynton, lower bridge, Maple River Valley, Emmet Co., July 4, 1949.

Observations.—In 1947 this was one of the common species of Inocybe in the region around Douglas Lake; its scarcity in 1949, when it was collected on only a single occasion, merely illustrates a vicissitude of collecting quite familiar to those of us who study agarics.

In its external characters—the red-brown, scaly pileus and the satiny, incarnate stipe—*Inocybe leptocystis* bears a strong resemblance to *I. subdestricta* Kauffm., but the two can be distinguished readily by their pleurocystidia. The pleurocystidia are, in fact, the principal distinctive characteristic of *I. leptocystis*. They exemplify the type which Kauffman (1921, p. 47) designated as "thin-walled cystidia," and are quite constant in all the collections I have examined.

Inocybe melanopoda, sp. nov.

(Pl. II, Figs. 1–2; Pl. V)

Pileus 2–6.5 cm. latus, convexus vel obtuse campanulatus, plerumque late umbonatus, primo sericeo-fibrillosus, mox omnino diffracto-squamulosus, pallide ochraceus vel sordide stramineus; caro pallida, immutabilis, odor aliquanto fortis, raphaneo-spermaticus; lamellae adnexae vel adnatae, subventricosae, 4–6 mm. latae, ex pallidis fusco-olivaceae; stipes 3–9 cm. longus, 4–10 mm. crassus, aequalis, basis non bulbosus, omnino fibrilloso-flocculosus, apice pallidus, deorsum ex pallidis fuscus; sporae 6.5–9.5 × 4.5–5.5 μ, leves, amygdaliformes; pleurocystidia 42–60 × 14–22 μ, ventricosa, apice obtuso, muro tenui praedita.

Pileus 2–6.5 cm. broad, usually 3–4 cm., hemispheric to obtusely campanulate, becoming expanded and broadly campanulate, finally plane, with or without (usually with) a low broad umbo, the margin

at first involute, becoming and long remaining broadly rounded, finally plane; surface at first overlaid by a continuous, thin, webby layer of pallid superficial fibrils, soon becoming disrupted into patches and streaks which persist for a time and then disappear, the cuticle itself a thick, densely appressed, fibrillose layer, becoming everywhere diffracted-imbricate-scaly, the squamules appressed or with free tips, or less frequently with the disc unbroken or merely areolate, and usually with the margin merely fibrillose or fibrillose-lacerate; color at first pallid ("cartridge buff," 11D3, 11D4), becoming uniformly some shade of buff or dingy straw color (raffia 11E5, "pinkish buff," India buff 12E5, 12E6, and so on), sometimes the center or the margin becoming a darker shade of brownish buff; context rather thick (4–9 mm. at edge of disc), firm, very compact, buff at the surface, pallid elsewhere, unchanging on exposure, odor somewhat variable but usually raphanoid-spermatic or fabaceous-spermatic, rather strong but not disagreeable, taste mild. Lamellae varying from adnexed to adnate, abruptly rounded or rounded-sinuate at the stipe, rounded to bluntly pointed at the margin, oblong or ventricose, moderately broad (4–6 mm. wide), rather close, from 60 to 80 reaching the stipe, with as many more inserted in varying lengths; color at first very pallid (oyster white 10B1, "cartridge buff"), remaining pale for a long time, then becoming some shade of grayish drab (parchment 12B3, 12D5, 13H6), finally deep olivaceous (bronze 14L9). Stipe 3–9 cm. long, 4–10 (15) mm. thick, usually 6–6.5 cm. × 5–6 mm., terete or frequently compressed, equal, the base not bulbous, the apex often flared; solid, the context soft at the center, but elsewhere quite tough and fibrous, pallid, unchanging on exposure, but gradually becoming flushed with dingy brown or brownish fuscous from the outside in and from the base upward; surface everywhere densely fibrillose or fibrillose-floccose, becoming fibrillose-punctate and conspicuously and rather coarsely longitudinally fibrillose-streaked, somewhat glabrescent only in old specimens, the base coated with a dense, pallid mycelium, the apex densely velvety and pruinate-granulose; color at first entirely white or pallid (10C3), remaining so at the apex, becoming more and more flushed from the base upward with shades of dingy brown ("cinnamon brown" to "clay color"), then with shades of drab or fuscous ("drab," camel's hair 14B6, woodbark 14B7, 14F7, and so on), finally becoming very dark brownish fuscous to fuscous or almost black (teakwood 15C9, 15J10, elk 16A11, "bistre," "mummy

brown," "olive brown," and so on), but appearing to be some shade of dingy gray because of the coating of paler superficial fibrils.

Spores 6.5–9.5 × 4.5–5.5 μ, mostly 8–9 × 5 μ, smooth-walled, inequilateral-amygdaliform, with straight to slightly concave dorsal profile, broadly rounded ventrally; pleurocystidia 42–60 (65) × (12) 14–22 μ, ventricose above a short, narrow pedicel, with a short, broad neck and a broadly rounded, obtuse to subcapitate apex, thin-walled, hyaline in KOH; cheilocystidia of two kinds, most of them slender, cylindric to clavate, about 34–56 × 7–14 μ, densely clustered along the edge of the lamella, but some resembling the pleurocystidia in size and shape; basidia 18–25 × 7–9 μ, four-spored; trama of the lamellae composed of compactly arranged, parallel, slender hyphae 7–9 μ in diameter, with cylindric to narrowly fusiform cells; surface of the pileus with two layers of radially oriented, parallel to loosely interwoven hyphae, the uppermost layer thin, consisting of rather loosely interwoven, slender, hyaline, thin-walled hyphae 3.5–5 μ in diameter, with occasional clamp connections and slightly punctate walls, the subtending layer much deeper and more compactly arranged, consisting of more or less parallel, brown, faintly encrusted hyphae which are rather variable in diameter and in the shape of the cells, about 13–18 μ thick; no lactifers seen.

Habitat.—Single to gregarious, on the ground in humus under either conifers or hardwoods, June and July.

Material studied.—Stz. 2867, coll. M. Lange, Univ. Mich. Biol. Sta., Douglas Lake, Mich., July 17, 1947; Stz. 2908, coll. T. Brooks, Harbor Springs, Mich., July 20, 1947; Stz. 3000, same locality as the preceding, July 23, 1947; Stz. 3641 (TYPE), grounds of Univ. Wash. Biol. Sta., Friday Harbor, Wash., July 15, 1948; Stz. 5018, coll. Paul Harding, Wolf's Bog, Cheboygan Co., Mich., June 29, 1949; Stz. 5104, coll. A. H. Smith, Molony Lake, Mich., July 6, 1949; Stz. 5165, coll. A. H. Smith, woods near Mackinaw City, Mich., July 11, 1949; Stz. 5191, coll. Chas. Arzeni, Wolf's Bog, Cheboygan Co., July 12, 1949; Stz. 5192, coll. A. H. Smith, "the Gorge," Univ. Mich. Biol. Sta., Douglas Lake, July 12, 1949; Stz. 5200, coll. A. H. Smith, Wolf's Bog, Cheboygan Co., July 13, 1949; Stz. 5218, woods near Mackinaw City, July 15, 1949; Stz. 5270, Pointe Aux Chenes, Mackinac County, Mich., July 19, 1949; Stz. 5316, 5326, woods near Mackinaw City, July 23, 1949; Stz. 5398, same locality as the preceding, July 28, 1949.

Observations.—The distinctive macroscopic characteristics of this species of Inocybe are its uniformly buff, imbricate-scaly pileus and its firm, densely fibrillose-peronate stipe which becomes suffused with grayish drab or fuscous from the base upward. Its chief distinguishing microscopic feature is the thin-walled pleurocystidium with broadly rounded to subcapitate apex, closely resembling the pleurocystidium of *I. leptocystis* Atk.

The only other species of Inocybe known to me with similarly colored pileus, smooth spores, and thin-walled pleurocystidia are *I. inconcinna* Karst., sensu Heim (1931, p. 248), *I. cylindrocystis* Atk., and *I. pallidobrunnea* Kauffm. From all three of these, *I. melanopoda* is readily distinguished by its fuscescent, fibrillose-peronate stipe. Its pleurocystidia are quite different from those of either *I. cylindrocystis* or *I. pallidobrunnea*, and, to judge from descriptions, the color of its pileus is not the same as that of *I. pallidobrunnea* or *I. inconcinna*. The spores of all four of these species are about the same size and shape.

In older specimens of *Inocybe melanopoda*, the center or the margin of the pileus may become rather dark-colored; in two of my collections (one being the type), I have notations of such shades as "snuff brown," calabash 14J7, or even buffalo 15L11 for these areas. Plants in the prime of their development, however, are characteristically a uniform shade of dingy buff or ochraceous buff. The layer of pallid superficial fibrils on the surface of the pileus varies in the degree of its development with different collections, but is usually evident at least on unexpanded pilei. The odor is also apparently rather variable; it seems to be basically spermatic, but with other components in addition, characterized as "subfarinaceous," "fabaceous," "fungoid" (i.e., like Lycoperdon) and varying from collection to collection.

Inocybe nigrodisca Peck, Ann. Rep. New York State Mus., 41: 67. 1888

(Pl. II, Figs. 3–4)

Pileus 4–13 mm. in diameter, most commonly 8 mm. broad, campanulate, becoming expanded and shallowly convex to plane or nearly so, with a small, low, rounded umbo, the margin narrowly involute at first, becoming plane; surface dry, entirely covered with a persistent webby layer of pallid-gray superficial fibrils which are more or less

radially oriented and which usually become arranged into tiny, appressed, triangular squamules except on the umbo, the pileus surface beneath this layer smooth and appressed-fibrillose; color brownish black ("bistre," "sepia," "mummy brown," "fuscous") on the umbo, elsewhere "cinnamon brown" to "tawny olive" or 13F7 when wet, becoming grayish ("drab," woodbark 14B7, camel's hair 14B6, grain 13B5) on drying; context thin (0.5 mm. thick at edge of disc), fragile, reddish brown when wet, drying pallid, unchanging on exposure, odorless. Lamellae slightly adnexed to narrowly adnate, broadly rounded at the stipe, pointed at the margin, asymmetric-ventricose, widest toward the stipe, not broad (1.5 mm. wide), not close, about 25 reaching the stipe, with as many more inserted in varying lengths; color at first grayish (13C6, 13D6), becoming olivaceous (14K9). Stipe 1–2.5 cm. long, 0.3–1.0 mm. thick, terete, equal, often flexuous, the base not at all bulbous; hollow, the context reddish brown, unchanging on exposure; surface everywhere densely granular-pruinate, satiny and subshining beneath the pruina; color reddish brown ("tawny," "russet," "Rood's brown," "Mikado brown," or "Vandyke brown").

Spores 6.5–8 × 4.5–5.5 μ, angular-nodulose, almost always with a bluntly conic apex, surface with about 10 small rounded nodules, principally at the corners, and always with one at the apex; pleurocystidia 45–60 × 11–14 μ, cylindric-subventricose, apedicellate, with rather broad base and tapering neck, very thick-walled (up to 4–5 μ), bright yellow in KOH; cheilocystidia of two kinds, one like the pleurocystidia in size and shape, the other short, clavate, thin-walled, about 16–22 × 9–12 μ; basidia 18–25 × 7–8 μ, four-spored; surface of the pileus with a superficial layer of slender, hyaline, more or less parallel, radially oriented hyphae 5–7.5 μ in diameter, thick-walled, with clamp connections at the rather widely separated septa, associated in broad, pointed fascicles (the squamules mentioned earlier in the description) toward the margin; beneath these superficial fibrils, the upper portion of the pileus trama forming a layer several cells deep of very compactly arranged, radially oriented hyphae, presenting an almost cellular appearance on the disc, the individual cells irregularly isodiametric to elongate-ellipsoidal, about 34–70 × 25–35 μ, with thin, brown walls which are usually encrusted with a brown pigment, the whole colored layer dark vinaceous brown in 2 per cent KOH.

Habitat.—Single to loosely gregarious, on the ground on humus

or in Sphagnum or other mosses under hardwoods or conifers, often in swampy places, June through September.

Material studied.—Stz. 2738, middle bridge, Maple River Valley, Emmet Co., Mich., July 12, 1947; Stz. 2984, coll. M. Lange, Mud Lake Bog, Cheboygan Co., Mich., July 22, 1947; Stz. 5023, 5036, coll. A. H. Smith, same locality as the preceding, June 30, 1949; Stz. 5562, Upper Tahquamenon Falls, Mich., Sept. 6, 1949.

Observations.—The species of Inocybe just described can be identified quite readily in Kauffman's monograph as *I. nigrodisca* Peck. It corresponds very well to such descriptions of this species as are available, and cannot be referred to any other American species with which I am familiar. Unfortunately, neither Peck nor Kauffman published any illustrations of the spores and pleurocystidia of *I. nigrodisca;* hence it is necessary to interpret their rather succinct description of these structures as best one can, and to identify collections as *I. nigrodisca* with some slight reservations. The same difficulty is encountered with the multitude of other species of Inocybe whose microscopic characteristics are not illustrated, but only described—all too frequently in a vague or unsatisfactory manner.

The description above of the plants referred to *Inocybe nigrodisca* checks point for point, *except in the matter of color of the pileus*, with that of *I. petiginosa* (Fr.) Gill. given by Kühner and Boursier (1932, p. 155). These authors, in commenting on the lack of mention of *I. petiginosa* in the American literature, express the opinion that *I. nigrodisca* may be synonymous. It seems to me that they may be right, at least in part: at any rate, my own comparison of what I am calling *I. nigrodisca* with *I. petiginosa* (which is not uncommon in Washington) indicates that the former differs only in the blackish color of its pileus, and perhaps should not be maintained at the level of a species. I naturally prefer, however, not to reach a decision in the matter until I have had the opportunity of studying the type of *I. nigrodisca* myself.

Inocybe patouillardi Bresadola, Annales Mycologici, 3: 161. 1905

(Pl. II, Figs. 5–6)

Pileus 4 cm. broad, 3 cm. high, persistently campanulate, the margin incurved, lobed and wavy; surface slightly lubricous when

moist, smooth, innately silky, unbroken, but becoming a little fibrillose-streaked toward the margin; color about "cinnamon buff" or 11F5 to cinnamon 12E7 (i.e., some shade of dingy buff), slowly turning red ("carrot red," "carnelian red," "vinaceous rufous") wherever touched or bruised; context firm, white, slowly turning red where exposed, odor faint but definitely aromatic, something like the flowers of nasturtium (Tropaeolus). Lamellae adnexed, gently and broadly rounded at the stipe, rounded to pointed at the margin, subventricose, not broad (4.5 mm. wide), rather close; color almost pure white at first and long remaining so, becoming dingy brownish, staining red where bruised. Stipe 5.5 cm. long, 9 mm. thick, terete, equal; solid, the context firm, white, slowly turning reddish where exposed; surface glabrous, satiny, shining, very faintly longitudinally silky-streaked; color pure white, staining red where bruised, and becoming more or less flushed with dingy ochre or buff at the base.

Spores 10–13.5 × 5.5–6–7 μ, subreniform, sometimes narrowed toward the apiculus; pleurocystidia lacking; cheilocystidia abundant, densely clustered all along the edge of the lamella, clavate, thin-walled, hyaline, 50–60 × 9–15 μ; basidia 34–38 × 11–16 μ, inflated-clavate, four-spored; surface of the pileus consisting of compactly arranged, radially oriented, parallel hyphae 4–7 μ in diameter, thin-walled, hyaline or with a brownish membrane pigment, sometimes with faint irregular incrustations, forming a layer many cells deep which merges below into the more loosely arranged trama of the pileus, with rather numerous clamp connections.

Habitat.—Single, on the ground in humus on a steep bank in a stand of mixed hardwoods.

Material studied.—Stz. 5370, coll. A. H. Smith, woods near Mackinaw City, Mich., July 28, 1949.

Observations.—So far as I am aware, this is the first report of *Inocybe patouillardi* from North America. It seems curious that a species of Inocybe as distinctive and as widely distributed throughout Europe as *I. patouillardi* should not have been found here before this, and one is tempted to think that it may have passed under a different name previously. There is no evidence in the literature to support such an idea, however, and it may actually be as rare a species in the United States as our experience thus far seems to indicate.

Inocybe rufidula Kauffman, North American Flora, 10: 253. 1924

(Pl. II, Figs. 7-8)

Pileus 0.5–2 cm. broad, campanulate and umbonate, with involute margin, becoming expanded and campanulate, finally plane to shallowly concave, with a small rounded umbo, the margin eventually plane; surface smooth, dry, appressed-fibrillose, remaining unbroken on the disc and usually also on the margin, or else becoming a little rimulose or fibrillose-lacerate toward the margin, but neither truly rimose nor scaly; color "Sayal brown" to "cinnamon" or 13E8 or 14C9, flushed with "cinnamon rufous" at the margin; context thin, pallid with a rufous tinge, unchanging on exposure, odor raphanoid-spermatic. Lamellae adnexed, broadly rounded at stipe and margin, symmetrically ventricose, rather broad (up to 4 mm. wide), not close, about 40 reaching the stipe, with as many more inserted; color grayish brown (14D8), becoming olivaceous (14I8). Stipe 1.5–6 cm. long, 0.5–3.0 mm. thick, terete, equal, flexuous, the base not at all bulbous; narrowly hollow, the context pallid rufous, unchanging on exposure; surface satiny and almost glabrous below, with patches and longitudinal streaks of "rufous" fibrils, only the extreme apex pruinate; color "pinkish cinnamon" below, "cinnamon rufous" above.

Spores 9.5–12 (13.5) × 5–6 μ, smooth-walled, inequilaterally amygdaliform, with dorsal suprahilar flat or shallowly depressed area, broadly rounded ventral profile, and pointed apex; pleurocystidia 45–72 × 14–20 μ, ventricose above a slender pedicel, with broadly rounded apex, sometimes subcapitate, thin-walled; cheilocystidia of two kinds, some resembling the pleurocystidia in size and shape, but the majority short, inflated-clavate, 23–38 × 11–18 μ; basidia 22–30 × 8–10 μ, four-spored; surface of the pileus with a thin, rather loosely organized upper layer of hyphae 7–13.5 μ in diameter, hyaline or pale brownish, with numerous clamp connections and faint irregular incrustations, and beneath this a much more compactly arranged layer of brown-walled, parallel hyphae of somewhat greater diameter which merges with the trama of the pileus.

Habitat.—Single to gregarious, on the ground in humus in swampy areas under hardwoods, July and September.

Material studied.—Stz. 2777, coll. M. Lange, middle bridge, Maple River, Emmet Co., Mich., July 14, 1947; Stz. 5493, coll. A. H. Smith,

Lower Tahquamenon Falls, Mich., Sept. 2, 1949; Stz. 5500, same date and locality as the preceding.

Observations.—This is a distinctive species, readily recognized in the field by the bright rufous color of its stipe and, to a lesser degree, of its pileus. In my opinion it is most closely related to *Inocybe leptocystis* Atk., with which it has in common the thin-walled, capitate pleurocystidia and the general color scheme of reddish pileus and incarnate stipe, and from which it differs in its much brighter rufous colors, more slender habit, and larger spores.

Inocybe subexilis (Peck) Saccardo, Sylloge Fungorum, Vol. V, p. 785. 1887

(Pl. II, Figs. 9–10)

Pileus 4–12 mm. in diameter, broadly campanulate and umbonate, with narrowly rounded margin, expanding and becoming shallowly campanulate with a prominent mammillate umbo, the margin shallowly arched to plane; surface dry, smooth (rarely a little diffracted in dry weather), appressedly fibrillose, seemingly without any pallid superficial fibrils, but actually minutely hoary when examined with a lens, and occasionally with the hoariness developed enough to be seen without a lens, a conspicuous superficial layer of pallid fibrils, however, definitely absent; color reddish brown ("chestnut," "Sanford brown," "russet," "auburn") at the center, paler and more yellowish brown ("cinnamon buff," Sayal brown 13G9) on the margin; context 0.5–1.0 mm. at edge of disc, firm, pallid, unchanging on exposure, without any odor. Lamellae adnate, shallowly emarginate or sinuate and rounded-depressed at the stipe, bluntly pointed at the margin, symmetrically ventricose, moderately broad (1–2 mm. wide), not close, about 30 reaching the stipe, with as many more inserted in various lengths; color at first pallid (10C2 to ecru 11C2), becoming yellowish olive gray (11H5), finally dingy olivaceous (Isabella 14K7). Stipe 1–3 cm. long, 0.75–2 mm. thick, terete, equal, often flexuous, the base not at all bulbous; solid, the context tinged incarnate or reddish, unchanging on exposure, but tending to fade to yellowish in age; surface everywhere finely and often densely pruinate, satiny beneath the pruina, sparsely white-silky toward the base in some; color at first vinaceous incarnate (13B7, 13C7, "fawn color"), or in

some cases reddish brown (13F9, "Mikado brown"), fading to yellowish colors ("warm buff," "cream color," 11E3) with age.

Spores 6–8 (9) × 5–6 μ, predominantly subtriangular in outline, with pointed apex, sometimes merely angular-oblong, with 10 or more small, rounded nodules; pleurocystidia 45–63 × 11–18 μ, varying in shape from ventricose above a long broad pedicel to jug-shaped and completely apedicellate, usually with a tapering neck, very thick-walled, pale to bright yellow in KOH; cheilocystidia of two kinds, one like the pleurocystidia in size and shape, the other small, inconspicuous, clavate, thin-walled, hyaline, 20–27 × 8–9 μ; basidia 18–25 × 7–8 μ, short-clavate, four-spored; surface of the pileus composed of two distinct regions, the lower one a shallow, compact layer (30–60 μ deep) of hyphae which are radially arranged and directed upward at a slight angle, the individual cells short-cylindric, variable in size and shape, crowded against each other, thin-walled, and with a membrane pigment which is bright fulvous in KOH; these cells giving rise, through the intermediary of three or four cells of diminishing diameter and progressively less-colored walls, to long, slender (2.5–5 μ in diameter), thin-walled, hyaline filaments with rounded free ends, which are more or less parallel and together constitute the "epicutis" or upper of the two regions mentioned; clamp connections present on the slender filaments of the "epicutis."

Habitat.—Single to gregarious, on the ground in swampy places in humus or among mosses under conifers or in mixed conifer-hardwood stands.

Material studied.—Stz. 2560, coll. M. Lange, "the Gorge," Univ. Mich. Biol. Sta., Douglas Lake, Mich., July 3, 1947; Stz. 2688, 2689, coll. M. Lange and D. E. Stuntz, same locality as the preceding, July 10, 1947.

Observations.—The identification as *Inocybe subexilis* of the collections cited above is subject to the same reservations as were mentioned in connection with *I. nigrodisca* Peck. Although the specimens agree well enough with the available descriptions, it is difficult to be certain of the exact nature of the spores and the pleurocystidia of *I. subexilis*, not to mention the nature of its pileus surface.

The absence of a conspicuous superficial layer of pallid fibrils—or, rather, its reduction to a few hoary fibrils best seen under a lens—gives *Inocybe subexilis* an appearance quite different from that of

I. petiginosa (Fr.) Gill., to which it is in other respects very similar. This difference was pointed out particularly by Morten Lange, who is, of course, familiar with *I. petiginosa* as it occurs in Europe and who studied the specimens on which my description is based.

Inocybe subexilis is one of a most confusing series of forms which includes *I. nigrodisca*, *I. petiginosa*, and, in addition, several other "entities" represented in my collections which differ in one way or another from any of these species. All of the forms have in common a set of rather striking microscopic characteristics: (1) small, angular-nodulose spores which are predominantly subtriangular in profile (i.e., narrowed toward the apex); (2) very thick-walled pleurocystidia, characteristically with a broad base and a sublanceolate neck, pale to bright yellow in 2 per cent KOH; and (3) a pileus surface composed of a compact layer of colored hyphae that give rise to long, slender, hyaline terminal filaments which together form the more or less well-developed "epicutis," or superficial layer. As regards their external appearance, the members of this "series" differ rather widely. One might be tempted to regard all of them as constituting a single, extremely variable species—*I. petiginosa*—but I for one would be reluctant to do so. For one thing, it seems to me that such a procedure has, in certain instances where it has obviously been adopted (i.e., *I. brunnea* Quél. sensu Heim, or *I. obscura* (Fr.) Gill. sensu Heim), resulted in more confusion, rather than in clarification; and for another, if *I. petiginosa* is so variable in North America, why has not a similar variability been revealed in Europe, where the species has been carefully studied? So, for the time being, I shall continue to regard *I. nigrodisca* and *I. subexilis* as autonomous species.

Inocybe tahquamenonensis, sp. nov.

(Pl. II, Figs. 11–13; Pl. VI)

Pileus 1.5–3.5 cm. latus, obtuse campanulatus vel plerumque convexus et exumbonatus, omnino eximie squarrosus, purpureo-fuscus, caro punicea, aëris contactu lente obscurans, odor debilis, vix notabilis; lamellae adnatae, ventricosae, 5–8.5 mm. latae, vix confertae, ex purpureo-vinaceis obscure umbrinae; stipes 3.5–7.5 cm. longus, 3–8 mm. crassus, aequalis, basi non bulbosus, squamis fibrilloso-floccosis obtectus, pileo concolor vel pallidior; sporae 6–8.5 × 5–6 μ,

anguloso-tuberculatae; pleurocystidia 70–90 × 14–18 μ, cylindraceo-subventricosa, muro tenui praedita.

Pileus 1.5–3.5 cm. broad, obtusely convex or obtusely campanulate, with involute margin, becoming expanded and broadly campanulate, finally plane, with a low, broad umbo or more frequently with none; surface from the very first squarrose from the center to the margin, with narrow, pointed, pyramidal squamules, becoming more or less denuded and excoriate with age; color from the first a very dark shade of brownish vinaceous fuscous or purplish fuscous, near "light seal brown" or Java brown 8J8 but much darker than either of these colors, not changing with age; context 2–3 mm. thick at edge of disc, hard, compact, reddish vinaceous ("light Corinthian red," "deep vinaceous," "dark vinaceous," or "dark Indian red"), unchanging when first exposed, but upon long exposure (from 6 to 10 hours) slowly darkening to almost the color of the pileus, odor very faint, slightly raphanoid, or lacking, taste mild. Lamellae adnate, deeply and abruptly rounded close to the stipe, pointed at the margin, asymmetric-ventricose, widest toward the stipe, moderately broad to quite broad (5–8.5 mm. wide), not close, about 35 reaching the stipe, with twice as many inserted in two series of approximately equal lengths; color at first "deep vinaceous" to "purplish vinaceous," passing through "vinaceous brown," then "dark vinaceous brown" to "seal brown," and finally becoming "cameo brown" or "burnt umber" as the spores mature, the edges finely dentate, darker-colored, "chocolate" to "dark vinaceous brown." Stipe 3.5–7.5 cm. long, 3–5–8 mm. thick, terete, equal, often flexuous, the base not bulbous, but usually more or less bluntly tapered; solid, the context rather loosely fibrous along the axis, hard, compact, subcartilaginous at the surface, color same as that of the pileus context, or "Eugenia red" in the upper portion, more nearly "chocolate" to "dark vinaceous brown" below, unchanging on exposure at first, but slowly darkening in several hours to the same color as the exposed pileus trama; surface everywhere densely squarrose like the pileus surface, the squamules becoming more widely separated and more or less pulled into longitudinal streaks as the stipe elongates, the surface beneath the scales rough-fibrillose, longitudinally striolate; color same as the pileus surface or a little paler, "Hay's brown" to Java brown 8J8 or Hindu 8J9.

Spores 6–7–8.5 × 5–6 μ, angular-nodulose, usually short-oblong,

but often rather variable in outline, with 6–8–12 rather large, rounded nodules; pleurocystidia 70–90 × 14–18 μ, cylindric-subfusiform, with slender, short pedicel and obtuse apex, with or without a thin globular cap of amorphous material, thin-walled, usually with pale vinaceous-incarnate or lilac content; cheilocystidia a mixture of clavate cells about 60 × 22 μ and clustered filaments of from two to four or five cells, very variable in length, but often extending nearly 0.5 mm., with clavate to cylindrical terminal cells up to 105 × 20 μ, occasional cells resembling the pleurocystidia also present, all these cells with purplish intracellular pigment and faint to dark-colored walls, often with irregular, faint-banded incrustations; basidia 30–34 × 7–9 μ, four-spored; lamellar trama parallel, composed of short, inflated-cylindric cells 30–35 × 14–21 μ, lactifers often present; surface of the pileus a dense layer of more or less parallel, repent hyphae which are gathered into sharply ascending or vertical broad fascicles to form the squamules of the pileus, the individual cells of these hyphae cylindric to bone-shaped, with many inflated, almost globose, ones intermingled, most of the cells with a very dark vinaceous-brown membrane pigment, and sometimes also with banded incrustations; clamp connections numerous; lactifers with vinaceous-brown content often very numerous in the trama of the pileus.

Habitat.—Single or in groups of two or three, on the ground in humus in stands of mixed hardwoods.

Material studied.—All the collections cited were made by A. H. Smith, at Upper Tahquamenon Falls, Mich.: Stz. 5555 (TYPE), Sept. 6, 1949; Stz. 5609, 5610, Sept. 11, 1949; Sm. 39456, 39473, Sept. 11, 1952.

Observations.—The fuscous-purple, densely scaly pileus and stipe and the purplish-vinaceous lamellae give this species an aspect which is scarcely suggestive of the genus Inocybe; in fact, Dr. A. H. Smith has very aptly compared its appearance to that of rather old, somewhat weather-beaten, depauperate specimens of *Cortinarius violaceus* Fr. It is certainly quite unlike any other species of Inocybe known to me. None of the rough-spored species which have purplish or lilac colors (*I. fulva* Rea, *I. fulvella* Bres., *I. ionipes* Boud., for example) are at all similar in other respects to *I. tahquamenonensis*. Two American species with a combination of characteristics similar to those of *I. tahquamenonensis*—i.e., scaly pileus and stipe, nodulose spores, and thin-walled pleurocystidia—are *I. longicystis* Atk. and

I. stellatospora (Peck) Massee, but neither of these shows any purple color. A fragment of the type of *I. stellatospora* present among Atkinson's collections at Cornell University has spores and pleurocystidia very similar to those of *I. tahquamenonensis*, and it may be that there is some degree of relationship between these two species, in spite of their striking difference in color.

The lilac to vinaceous- or purplish-brown intracellular pigment, or pigments, present in most of the cells is readily extracted, and exhibits very little alteration in color (it becomes slightly more reddish) when either fresh or dried tissues are mounted in 3 per cent KOH. Many of the cells (pleurocystidia, cheilocystidia, cuticular fibrils) also have a colored wall (membrane pigment), which in the cuticular fibrils may be quite dark brown.

If one examines the spores of *Inocybe tahquamenonensis* carefully, one sees that the peculiar distorted appearance of some of them is due to their having one or more nodules of a somewhat abnormal type. These nodules are quite broad, with a wide, flat, truncated apex, and in some of them the apex bears two or three low, indistinct "secondary nodules." Such compound nodules might be considered to represent a slight degree of development of the condition which reaches an extreme in the spores of *I. multicoronata* A. H. Smith.

Inocybe tubarioides Atkinson, Am. Journ. Bot., 5: 217. 1918.

Habitat.—Single or gregarious, on rotten logs in stands of mixed hardwoods, July.

Material studied.—Stz. 2882, coll. M. Lange, Grapevine Point, Univ. Mich. Biol. Sta., Douglas Lake, Mich., July 19, 1947; Stz. 5084, same locality as the preceding, July 5, 1949.

Observations.—For a description of this unusual species of Inocybe the reader is referred to the paper published by A. H. Smith and L. R. Hesler (1938, p. 264). The establishment of the presence of *I. tubarioides* in Michigan represents a further extension of its known range, which now comprises New York, North Carolina, Tennessee, and Michigan. Fresh specimens have little of the appearance of other members of the genus, and the habitat on rotting wood is also unusual. Either it is actually a rare plant or it is easily overlooked, for so far as I am aware, only the two collections cited by Smith and Hesler and the two cited in this paper are known, in addition to the type.

Inocybe umbrinella Bresadola, Annales Mycologici, 3: 161. 1905

(Pl. II, Figs. 14–15)

Pileus 1.5–4.5 cm. broad, narrowly campanulate at first, becoming expanded and more broadly campanulate, with a very prominent mammiform umbo, the margin broadly incurved, eventually becoming plane; surface dry, smooth, innately silky and shining, remaining unbroken on the umbo, soon becoming conspicuously and rather coarsely long-rimose elsewhere, the cuticle forming long, narrow, radial strips; color umbrinous ("warm sepia," "cinnamon brown," burnt umber 15A12, 8J12), paler toward the margin (roe 12H6, maple 11E4), where the context is exposed; context firm, white, unchanging on exposure, odorless. Lamellae adnate, broadly and shallowly rounded toward the stipe, pointed toward the margin, subventricose, not broad (5 mm. wide), moderately close; color dingy grayish olivaceous, becoming darker olivaceous (13F5 to 14H6), with pallid edges. Stipe 3.5–9 cm. long, 3–6 mm. thick, terete, equal, or a little incrassated downward, the base abrupt but not bulbous; solid, the context firm, rather fibrous, pallid, unchanging on exposure, but becoming umber at the base in age; surface appressed-fibrillose, silky-streaked, dull satiny, remaining so above, glabrescent below; color white or tinged with pallid buff ("cream buff" to "cartridge buff"), in some becoming flushed with "cinnamon brown," in others not, but in most becoming dark brown ("sepia") at the base.

Spores 10.5–12.5–14 × 6–7 μ, subreniform; pleurocystidia lacking; cheilocystidia 38–56 × 10–14 μ, clavate to subventricose and subcapitate, with obtusely rounded apex, thin-walled, hyaline; basidia 30–38 × 9–11.5 μ, four-spored; surface of the pileus with two layers, the uppermost three or four cells deep and composed of parallel, radially oriented, slender, hyaline, thin-walled hyphae 4–5 μ in diameter, with clamp connections at nearly every septum, the layer underlying this four or five cells deep, composed of much larger hyphae, 18–22 μ in diameter, very compactly arranged, parallel, with thin walls having very conspicuous banded incrustations of brownish-fulvous pigment; lactifers not seen in any tissues.

Habitat.—Single or scattered in small groups, on the ground in humus in stands of mixed hardwoods, July.

Material studied.—Stz. 5215, 5219, woods near Mackinaw City,

Mich., July 15, 1949; Stz. 5328, coll. A. H. Smith, same locality as the preceding, July 23, 1949.

Observations.—The relationship of this species to *Inocybe fastigiella* Atk. and to *I. armoricana* var. *phaeoderma* Stuntz has already been discussed in connection with the latter. From *I. brunnescens* Earle and *I. glaber* Kauffm., two other umber-colored species of Inocybe with smooth spores and without pleurocystidia, *I. umbrinella* differs in its spore size and in the nature of the surface of its pileus, as well as in other minor details. It is apparently less common than *I. fastigiella*—at least, this seems to be the first published report of its presence in Michigan.

Heim (1931, pp. 188–189) reduces *Inocybe umbrinella* to the status of a variety of *I. fastigiata* (Fr.) Quél., and it may be that he is right in so doing, as the chief difference between them lies in the color of the pileus. However, I am inclined to think that he makes the species limits a little too inclusive in the case of *I. fastigiata*, and so I prefer, for the present at least, to follow Kauffman and Bresadola in maintaining *I. umbrinella* as an autonomous species.

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Note

The drawings in Plates I–II were made with the aid of a camera lucida, and the magnification of the cystidia is approximately 730, unless otherwise stated; that of the spores is approximately 1,500.

EXPLANATION OF PLATE 1

Fig. 1. *Inocybe armoricana* var. *phaeoderma*, cheilocystidia
Fig. 2. *I. armoricana* var. *phaeoderma*, seven spores
Fig. 3. *I. cervicolor*, cheilocystidia
Fig. 4. *I. cervicolor*, five spores
Fig. 5. *I. cryptocystis*, portion of the hymenium showing two pleurocystidia
Fig. 6. *I. cryptocystis*, three pleurocystidia
Fig. 7. *I. cryptocystis*, five spores
Fig. 8. *I. descissa* var. *macrospora*, pleurocystidia
Fig. 9. *I. descissa* var. *macrospora*, five spores
Fig. 10. *I. godeyi*, four spores
Fig. 11. *I. godeyi*, two pleurocystidia
Fig. 12. *I. intricata*, two pleurocystidia
Fig. 13. *I. intricata*, four spores
Fig. 14. *I. leptocystis*, three pleurocystidia
Fig. 15. *I. leptocystis*, four spores

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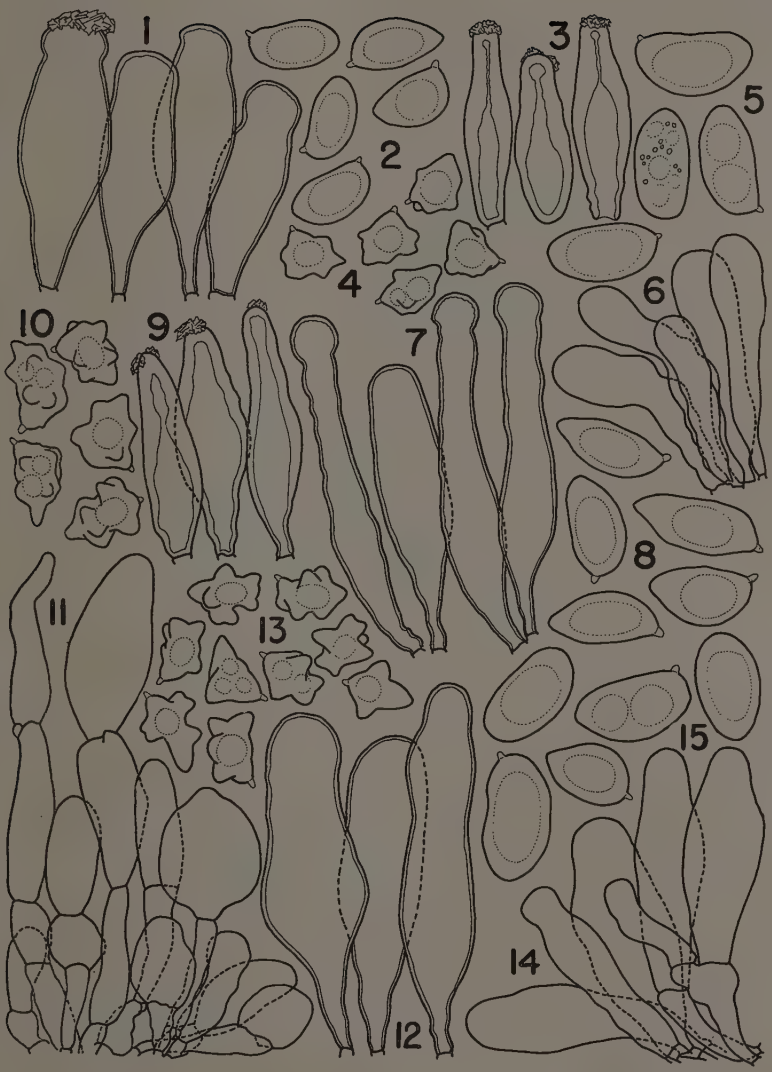
EXPLANATION OF PLATE II

FIG. 1. *Inocybe melanopoda*, pleurocystidia
FIG. 2. *I. melanopoda*, five spores
FIG. 3. *I. nigrodisca*, pleurocystidia
FIG. 4. *I. nigrodisca*, five spores
FIG. 5. *I. patouillardi*, four spores
FIG. 6. *I. patouillardi*, cheilocystidia
FIG. 7. *I. rufidula*, four pleurocystidia
FIG. 8. *I. rufidula*, five spores
FIG. 9. *I. subexilis*, three pleurocystidia
FIG. 10. *I. subexilis*, five spores
FIG. 11. *I. tahquamenonensis*, cheilocystidia, × 390
FIG. 12. *I. tahquamenonensis*, pleurocystidia, × 730
FIG. 13. *I. tahquamenonensis*, nine spores
FIG. 14. *I. umbrinella*, cheilocystidia
FIG. 15. *I. umbrinella*, five spores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Inocybe armoricana var. *phaeoderma* Stuntz. × 1

Inocybe cryptocystis Stuntz. × 1

Inocybe melanopoda Stuntz. × ⅔

Inocybe tahquamenonensis Stuntz. × 1 (Photograph by A. H. Smith)

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DISTRIBUTION OF MARINE ALGAE IN THE GULF OF MEXICO

WM. RANDOLPH TAYLOR

Introduction

THE marine flora of most of the shoreline of the Gulf of Mexico is the least known flora of any part of our coast. This is true for the west coast of Florida and for Texas, but even more so for the other Gulf states, for Mexico, and for Cuba. To be sure, part of the Cuban and southern Mexican shoreline is rocky, but much of the western and northern Gulf coast is swampy or sandy. Though towns where port facilities can be established occur along the Mexican coast, at considerable intervals, and though there is some resort activity in the vicinity of sandy beaches that are near towns, the useful agricultural land lies inland and a good share of the coastline is unproductive and difficult of access. These same limitations, in varying degrees, have restricted observations on the marine algae north of the Rio Grande. A swampy or a sandy region discourages a luxuriant and varied marine algal flora, but even in such regions jetties, pilings, shell mounds, mangroves, and submerged marine phanerogams offer a foothold for the larger algae, and in the southern sectors good situations for algal development must be common.

Early knowledge of the Gulf algae came chiefly from the records of Cuban (Montagne, 1842), of Mexican (J. G. Agardh, 1847), and of Floridian algae, especially from Key West (Harvey, 1852–58). It was extended but slowly, although records from other Florida stations, notably ones on the Keys, did accumulate. The absence along the coast of institutions interested in marine biology was one delaying factor. The former Carnegie Institution station on the Dry Tortugas, westernmost outpost of the Keys, and the accessibility of the shoreline and reefs all along the Keys and the Florida east coast, made the flora of this region relatively well known (Taylor, 1928). In the last twenty-five years marine stations have been established along the northern and western arcs of the Gulf, some substantial collections

have been made, and reports are beginning to appear (Nielsen and Madsen, 1949; Madsen and Nielsen, 1950) that will eventually give a clear idea of the vegetation. I have assembled the available Mexican material (Taylor, 1935, 1941b) and that from Texas (1936, 1941a, 1941b), and have nothing substantial to add here from those regions. Regarding Cuba, the publications of Montagne (1842), Howe (1918), Sánchez Alfonso (1930), Castellanos (1945), and myself (Taylor, 1941b) cover most of the information gathered in the past, but now three collections which have been entrusted to me for study permit a very considerable increase in our knowledge of Cuban algae, including for the first time records from the southeast coast, which, though it does not face on the Gulf of Mexico, is of importance in furnishing material for comparison. Two additional collections yield data on Louisiana, Mississippi, and the Florida Gulf Coast algae. On the basis of these collections and the published reports, I propose to attempt a sketch, necessarily superficial and preliminary, indicating in general terms what the algal vegetation (exclusive of the Myxophyceae) may be like. I prepared a similar but more detailed sketch and a comprehensive bibliography only a few years ago for an as yet unpublished government bulletin (P. S. Galtsoff, editor), but it did not have the benefit of these latest collections. A station list for these new records appears below (pp. 93–108).

Distribution of Algae

The marine algal flora of eastern Mexico is almost entirely unknown, although the Yucatan peninsula early enters algal records with the report of a species of Sargassum from Campeche by Liebmann (Agardh, 1847) and with substantial collections by Schott in 1865 and by Steere in 1932 (Taylor, 1935, 1941b). We can recognize from these data that there are rocky as well as sandy stretches of coast and that the flora is the typical Caribbean type. The number and size of the collections do not suffice to establish the flora as a rich one, but certainly no major groups are conspicuously lacking. The limestone rock, sand, and mud of Yucatan is reported to give way westward to a swampy, muddy coast where mangroves are conspicuous, as at Río Tonalá. Northward the shores are more sandy, but lava flows supply rocky stretches and coral reefs do occur offshore, as near Vera Cruz. Here, also, Liebmann collected a very few algae, which Agardh (1847) described. There are no reasons

either from the terrain or the small collections made by Liebmann to assume a scarcity of marine algae.

As one goes yet farther northward there seem to be fewer opportunities offshore for algae, and the sandy character of the coast becomes more continuous, the composition less calcareous. The sandy barrier islands which occur as one approaches the Rio Grande practically preclude a substantial algal flora. The coastline from Tampico to the Rio Grande is particularly sparsely inhabited and as inhospitable to man as it is unfavorable to marine vegetation. In fact, there are few centers along the whole coast where good facilities for marine research could be established, so the prospects for a comprehensive study of the algal flora are very slight.

The Texas algal flora is much better known, though far from completely so. The coastline is still an unfavorable one for algae, being sandy, often with sandy barrier islands. There are, however, active scientific centers with easy access to the coast, and considerable collections of algae have been made. I have reported on these (Taylor, 1941a). The flora continues to be typically Caribbean, but is definitely restricted, consisting of about sixty species. The limitation of the flora appears in the suppression of the Codiaceae and the Caulerpaceae, many species of which might be expected in the lagoons behind the barrier islands, but which have not as yet been reported. On the muddy shores of these islands, as at Padre Island, there is, instead, a widespread development of particularly thick, firm crusts of Myxophyceae. However, about Corpus Christi and Copano Bay there remains quite a range of tropical and subtropical algae, such as *Ulva fasciata*, *Cladophora fascicularis*, Acetabularia, Batophora, *Corallina cubensis*, Laurencia, and the like, growing on jetties, wharves, pilings, or other solid supports.

The northeastern Texas flora seems further reduced, being in fact very poor indeed, with almost no tropical element; so far as our records go, it is dominated by such ubiquitous plants as *Ulva lactuca*, *Agardhiella tenera*, and *Gracilaria confervoides*.

One can hardly consider the marine algal flora of Louisiana, Mississippi, and Alabama other than as the sparsest on our coasts. Even the expected Gracilaria and Agardhiella species do not appear in the current collections. Much of the shore is sandy and sterile. The salinity of the sea water is perceptibly less. Where mud, shells, jetties, or the like occur, Rhizoclonium, Vaucheria, Enteromorpha,

and Myxophyceae are found. The presence of black mangroves permits the development of Bostrychia and Caloglossa on their pneumatophores, and these also appear on other objects. On rocks or pilings in shallow water *Polysiphonia subtilissima* and species of Ectocarpus grow. Attached sargassums are found a little deeper, and the pelagic species sometimes drift ashore. Compsopogon is present in the tidal streams, extending seaward toward where Bostrychia and Polysiphonia are found. There seems to be nothing to serve to distinguish between the floras of Louisiana and Mississippi. The causes for the impoverished north- and northwest-shore flora include the unstable substrate, the chilling of the water in winter, and a somewhat reduced salinity. Though we can add nothing regarding Alabama algae, the short coastline, with Mobile Bay receiving considerable river water, does not promise much variety. For all three states, hardly a dozen marine algae have been recorded.

West Florida starts out similarly, so far as the algal flora is concerned. The sargassums found at Gulf Beach in Escambia County had been washed ashore, but along the coast of Santa Rosa and Okaloosa counties large bays sheltered by barrier islands permit a distinct increase in the flora, and Gelidium, Ceramium, Digenia, Chondria, and Polysiphonia species appear on rock jetties. This is not much, but it is promising. Not all stations are equally good, but St. Andrews Bay, in Bay County, adds Aegira, Sphacelaria, and Champia, which are equally able to grow in temperate and tropical waters. The shore of Gulf, Franklin, and Wakulla counties, accessible from the marine station on Alligator Point, has been more thoroughly surveyed than any other area along the north shore, and Humm (1953) reports forty-seven species (excluding four of the Myxophyceae) from the limestone reefs in from eight to ten feet of water in Apalachee Bay. The very brief visits of our correspondents have yielded for the present list about forty-five species in the more limited flora of the immediate shore. They did not secure some of the more tropical genera that Humm lists in his abstract. As his species list has not been published, it is not possible to say just how many algae have been secured in this tricounty area, but perhaps an estimate of from sixty to seventy-five species would be reasonable. This is very small for so extensive a shoreline, when compared with the Keys.

The flora of Taylor County, as we have it represented, is far poorer. There is less variety of habitat available here, much of the

shore being swampy; yet Batophora, Dasycladus, and Sporochnus do appear, all well known in the tropics. The next stations, on the Cedar Keys in Levy County, do not seem any better, though they lie offshore and though red mangroves are known this far north. From the earlier series studied and reported (Taylor, 1936), we know that there is a relatively good flora in Pinellas County, at Tarpon Springs, off the mouth of the Anclote River, and at Clearwater, whence we recorded some twenty excellently developed algae almost completely tropical in their affinities, including Acetabularia, Batophora, three species of Caulerpa, Halimeda, Penicillus, Dictyota, Eucheuma, and Laurencia. The area surrounding Tampa, in adjacent Hillsborough County, and Cortez Beach, in Manatee County, show less variety, but add such characteristic plants as *Caulerpa prolifera* and two species of Halymenia. In Lee County, about Fort Myers, Acanthophora and Dictyota, good tropical genera, are to be found. Finally, we refer to our earlier report for about a dozen species from Collier County, collected in the winter and not distinctively tropical.

In summary, we may accept it that the records are too scanty, particularly from the northeastern arc of the Gulf, to permit us to set limits to the algal flora, but nevertheless the assortment becomes very greatly narrowed, with fewer tropical species occurring as one goes northward and without any substitution of a north-temperate element. The algae of Florida number well over four hundred marine species, most of which occur in the Keys if not on the east coast, with the full Caribbean range represented. A number of these can grow as far north as the Apalachee Bay area, but except about Tampa and Cedar Keys we have no evidence that they do so to any extent. The flora of this northeastern region is probably less than a fourth as varied as that of the more favored sections.

We turn now to consider briefly the flora of Cuba. The northwest coast bounds a sector of the Gulf of Mexico. The terminal peninsula of Guanahacabibes is low and fringed with mangroves, but the north shore eastward from this shows alternating rocky and sandy conditions along the coast (the sandy Bahía Mariel, for example), with at times broad stretches of shallow water far out from shore, where species of Thalassia and, doubtless, attendant algae grow, as near Habana. There are also the offshore Colorados Reefs, doubtless suitable for deeper-water species. Elsewhere the coast is equally varied, having at places muddy shallow bays, as at Bahía Cienfuegos, and at other places steeply rocky shores, as in the southeast, where,

however, small bays permit access to the algal flora. The topography, the absence of large rivers, the varied exposure, and the substrata favor a rich algal flora. Our list here includes over a hundred species; the earlier records add others which we cannot at the moment confirm. Altogether, it is clear that the Caribbean flora is well represented and that there are in all likelihood no major differences between the floras of the north and the south coasts of Cuba. Our present knowledge of from one hundred to one hundred and fifty species probably represents no more than a third of the whole number to be demonstrated when systematically organized studies have been carried out.

Sources of Material

The new data appearing in this paper are based on specimens submitted to me for identification by the United States National Museum Division of Cryptogams and by Drs. E. Yale Dawson, Francis Drouet, Roy N. Jervis, E. P. Killip, Ralph Lewin, E. Lowe Pierce, and F. K. Sparrow, Jr., for whose courtesies I am very grateful. Since a considerable number of collectors helped to secure these plants and many stations were visited, the data necessarily had to be condensed. The specimens have been ascribed to the collector whose name is given first on the label, and to the nearest distinctive locality so far as I could ascertain it, that being adequate for my present purpose. The chief collectors of the material submitted by Dr. Drouet from Louisiana, Mississippi, and Florida were Dr. Drouet himself and Dr. G. C. Madsen, who were assisted by E. M. Atwood, R. L. Caylor, D. Crowson, L. Elias, H. Harris, F. Higgenbotham, N. M. Hood, J. Linebaugh, H. B. Louderback, C. S. Nielsen, A. L. Pates, R. Thornton, and P. Viosca, Jr., in various groupings. R. O. S. Breen, D. Crowson, and H. Harris also contributed specimens from the area independently.

The specimens from Louisiana (Drouet *et al.*) were secured in November, those from Mississippi (Drouet *et al.*) in December. Florida material from most of the counties for which there are reports was collected in December (Lewin) and January (Drouet *et al.*), and also through the spring months, including May (Madsen *et al.*), and in August (at Cedar Key, by Pierce). The Isla de Pinos plants and some from western Cuba were collected (Killip) in December, January, and April. Most of the Cuban stations were visited (Daw-

son) in May, except those at the western end, which were visited by the Smithsonian-Roebling Expedition (Bartsch) in April, those near Guantánamo (Jervis), which were visited between September and March, and Bahía de Cienfuegos, at the Castella del Jugua, which was visited in April (Sparrow).

Descriptions of Localities

Louisiana.—Lafourche Parish collections were gathered in tidal streams between Leeville and Chenier Caminada. Intertidal collections were made in Jefferson Parish, south of Chenier Caminada, and similar gatherings were made on the shore of the Gulf of Mexico at Grand Isle. In Orleans Parish plants were collected from rocks and pilings in a tidal stream ten miles below Lake Pontchartrain.

Mississippi.—In Hancock County, between Waveland and Bay St. Louis on the shore of Mississippi Sound, specimens were secured from the intertidal zone, on the shore and on pilings, on shells, and on roots of higher plants. At Bay St. Louis they were found in a tidal marsh on the shore of St. Louis Bay. In Harrison County collections were made along the shore and on pilings in Mississippi Sound west of the lighthouse at Biloxi, and along the south shore of Back Bay. In Jackson County they were made along the shores of Biloxi Bay at Ocean Springs.

Florida.—Escambia County material was secured after it had been washed ashore on Gulf Beach, along the Gulf of Mexico. Santa Rosa County collections were made in the intertidal zone at Pensacola Beach, on the rocks of a causeway north of it, and in Santa Rosa Sound. In Okaloosa County, at Fort Walton, some material was secured that had been washed ashore. In Choctawatchee Bay intertidal collections were made at the east end of Santa Rosa Island. In Bay County specimens were taken from coves and shores of St. Andrews Bay west of the city as far as West Bay and Sunnyside, and from pilings in the bay at Panama City. Gulf County collections were made in the tidal streams and on the sand flats of St. Joseph Bay, near Port St. Joe and toward Cape San Blas. Franklin County had several productive stations. Some material was washed ashore in St. Vincents Sound, some collected from the intertidal zone in Apalachicola Bay. At the town of Eastpoint the plants came chiefly from a tidal stream. Several collections were made about Carrabelle, toward East Point, New River, the shores of St. Georges Sound at the

river mouth, and toward Carrabelle Beach. At Lanark specimens were secured along the shores of the Gulf, and others were gathered eastward, at Wilsons Beach and Ochlockonee Bay. Several sites on Alligator Point were visited, and a considerable variety of algae collected at Wayside Beach, Lighthouse Point, and in Alligator Bay. In Wakulla County the collections were made near the mouth of East River at St. Marks and on piling and stones in St. Marks River at Port Leon. Taylor County specimens were secured at Adams Beach, including the nearby Deakle and Keaton beaches. At Steinhatchee a gathering was made from pilings and from the shore of the Steinhatchee River, and another was made at the confluence of the river with Daughter Creek. Levy County is represented by intertidal collections on Way Key and Cedar Key of the Cedar Keys group—at Goose Cove, Piney Point, and on the Municipal Wharf, for example. Pinellas County yielded little, though a few specimens were found at Tides Beach, St. Petersburg. In Manatee County, across Tampa Bay, plants were gathered at Piney Point. In Lee County collections were made about Fort Myers, mostly at Fort Myers Beach and Sanibel Island.

Cuba.—In the province of Pinar del Río, Bahía Mariel on the north coast yielded collections of bottom algae in a sandy bay and of driftweed on the outer shore. Westward, at Puerto Esperanza, the algae came from the muddy bottom of a shallow bay. Isla de Pinos, lying to the south of Pinar del Río (but included politically), was visited at sandy Playa Nueva Gerona, where there was much Thalassia and Cymodocea, at Playa Columpo, which is shallow and sandy far seaward, and at Playa de Bibijagua, which is chiefly sandy toward the east but has black rocks in the westward part. The north coast of Habana province was sampled at Playa Marianao, and the south coast at Batabanó, where the pilings in the bay bore algae. In Matanzas province, Bahía Matanzas on the north coast, with sandy and rocky stations, had a good variety of plants; a few algae were secured from the rocks at Playa Varadera. In Las Villas province, Bahía Cienfuegos on the south coast yielded a few algae from about the Castella del Jugua and from the edges of a muddy lagoon. Camagüey afforded a more productive station at Tarafa, near Nuevitas, on the north coast. Oriente province was sampled at several south-coast stations. Bahía de Santiago was investigated at a small bay on the east side, below the El Morro trail. Four miles west of

Siboney a coral limestone coast where there was light surf also had a good variety of algae. Bahía Escondido had a few algae on coral boulders and yielded some that had been washed ashore on the beach. The Playa de Uvero, toward the Río Yateras, furnished a number of drifted specimens. Near Baitiquiri the pools on a coastal terrace also proved fruitful. Within the Guantánamo Bay Naval Operating Base area, Cable Beach and Kittery Beach, whose rocky shores include tidepools and sandy stretches, had a diversified flora.

List of Species

CHLOROPHYCEAE

ULVACEAE

Enteromorpha clathrata (Roth) Grev.—Often mixed with other algae in the collections, and hard to identify. The following records are probably to be assigned to this species. *Louisiana.* Orleans Parish: Lake Pontchartrain, A. M. Scott. Jefferson Parish: Grand Isle, Drouet *9501*. *Florida.* Bay Co.: St. Andrews Bay, Drouet *11427;* Panama City, Drouet *11598*. Franklin Co.: Carrabelle, Drouet *11701;* Wilsons Beach, Madsen *1037*.

Enteromorpha crinita (Roth) J. Ag.—This species is separable from *E. clathrata* with difficulty, if at all. Nevertheless, an attempt has been made to keep the two distinct in this account. *Florida.* Okaloosa Co.: Santa Rosa I., Drouet *10731;* Fort Walton, Drouet *10638*. Bay Co.: Panama City, Drouet *11608*. Franklin Co.: Lanark, Drouet *10846*. Wakulla Co.: St. Marks, Drouet *11464*, *11735*, Breen. Taylor Co.: Steinhatchee River, Drouet *11234;* Daughter Creek, Drouet *11216*. *Cuba.* Oriente: Siboney, Dawson *7708*.

Enteromorpha flexuosa J. Ag.—*Mississippi.* Hancock Co.: Waveland, Drouet *9830*, *9835;* St. Louis Bay, Drouet *9837*. *Florida.* Franklin Co.: Alligator Point, Madsen *1542*. Wakulla Co.: East River, Drouet *11781*. *Cuba.* Habana: Playa Marianao, Killip *41603*. Camagüey: Tarafa, Dawson *7605*.

Enteromorpha lingulata J. Ag.—*Louisiana.* Jefferson Parish: Chenier Caminada, Drouet *4973*. *Mississippi.* Hancock Co.: Waveland, Drouet *9832*. Harrison Co.: Back Bay, Drouet *10032;* Biloxi, Drouet *10006*. Jackson Co.: Ocean Springs, Drouet *9885*. *Florida.* Bay Co.: St. Andrews Bay, Drouet

11607. *Cuba*. Pinar del Río: Bahía Mariel, Dawson *7526*. Matanzas: Bahía Matanzas, Dawson *7764*. Las Villas: Bahía Cienfuegos, Sparrow, Dawson *7660*.

ENTEROMORPHA PLUMOSA Kütz.—*Florida*. Wakulla Co.: East River, Drouet *11782;* St. Marks, Drouet *11784*.

ENTEROMORPHA PROLIFERA (Müll.) J. Ag.—*Florida*. Okaloosa Co.: Santa Rosa I., Drouet *10725*.

ENTEROMORPHA RAMULOSA (Smith) Hooker.—*Florida*. Gulf Co.: Port St. Joe, Drouet *10946*. Levy Co.: Way Key, Drouet *11191*.

MONOSTROMA LATISSIMUM (Kütz.) Wittr.—*Florida*. Wakulla Co.: St. Marks River, Drouet *11790*. Levy Co.: Way Key, Drouet *11190A*.

ULVA FASCIATA Delile.—*Cuba*. Camagüey: Tarafa, Dawson *7639*.

ULVA LACTUCA L.—*Florida*. Bay Co.: St. Andrews Bay, Drouet *11426*. Franklin Co.: Eastpoint, Madsen *1553;* Carrabelle, Drouet *11715;* Alligator Point, Madsen *1060*, *1535*. Levy Co.: Cedar Key, Drouet *11204*. Manatee Co.: Piney Point, Lewin. *Cuba*. Camagüey: Tarafa, Dawson *7640*.

ULVA LACTUCA var. LATISSIMA (L.) DeCand.—*Mississippi*. Harrison Co.: Biloxi, Drouet *9957*, *10007*. *Florida*. Franklin Co.: St. Vincents Sound, Drouet *10989;* East Point, Drouet *11697*. Levy Co.: Way Key, Drouet *11190*, *11197*.

VALONIACEAE

ANADYOMENE STELLATA (Wulf.) C. Ag.—*Cuba*. Pinar del Río, Isla de Pinos: Playa Nueva Gerona, Killip *41649*. Oriente: Siboney, Dawson *7681;* Kittery Beach, Jervis *352*.

CLADOPHOROPSIS MEMBRANACEA (C. Ag.) Børg.—*Cuba*. Las Villas: Bahía Cienfuegos, Sparrow. Oriente: Siboney, Dawson *7685;* Cable Beach, Jervis *301;* Kittery Beach, Jervis *346*, *358*.

DICTYOSPHAERIA CAVERNOSA (Forssk.) Børg.—*Cuba*. Pinar del Río: dredged at seven meters' depth off Cayo San Felipe, Bartsch *93A;* Bahía Mariel, Dawson *7535*. Matanzas: Bahía Matanzas, Dawson *7777*. Oriente: Playa de Uvero, Jervis *9331*.

VALONIA MACROPHYSA Kütz.—*Cuba*. Dredged at seven meters' depth off the south coast, Bartsch *170E*.

VALONIA OCELLATA Howe.—*Cuba*. Oriente: Siboney, Dawson *7680;* Cable Beach, Jervis *532*.

CLADOPHORACEAE

CHAETOMORPHA AEREA (Dillw.) Kütz.—*Cuba.* Matanzas: Bahía Matanzas, Dawson *7755.*

CHAETOMORPHA BRACHYGONA Harv.—*Florida.* Levy Co.: Way Key, Drouet *11159* (det. Drouet). *Cuba.* Camagüey: Tarafa, Dawson *7611.*

CHAETOMORPHA MEDIA (C. Ag.) Kütz.—*Cuba.* Oriente: Bahía de Santiago, Dawson *7730.*

CLADOPHORA FASCICULARIS (Mert.) Kütz.—*Louisiana.* Jefferson Parish: Chenier Caminada, Drouet *9470. Florida.* Franklin Co.: Wilsons Beach, Madsen *1038.* Lee Co.: Fort Myers, Crowson *982. Cuba.* Matanzas: Bahía Matanzas, Dawson *7751.* Camagüey: Tarafa, Dawson *7606.*

CLADOPHORA FULIGINOSA Kütz.—*Florida.* Franklin Co.: Alligator Point, Dawson *11719. Cuba.* Pinar del Río: Bahía Mariel, Dawson *7519, 7551;* Isla de Pinos, Playa Columpo, Killip *41674.* Oriente: Siboney, Dawson *7682;* Playa de Verraco, Jervis *1881;* Playa de Uvero, Jervis *933H;* Baitiquiri, Jervis *13570;* Cable Beach, Jervis *306, 307.*

RHIZOCLONIUM RIPARIUM (Roth) Harv.—*Mississippi.* Harrison Co.: Biloxi, Drouet *10071. Florida.* Franklin Co.: New River, Drouet *10970.* (Both det. F. Drouet.)

DASYCLADACEAE

ACETABULARIA CRENULATA Lamx.—*Cuba.* Pinar del Río: dredged at four to nine meters' depth off Isla de Pinos, Bartsch *128A.* Las Villas: Bahía Cienfuegos, Dawson *7655.*

BATOPHORA OERSTEDI J. Ag.—*Florida.* Taylor Co.: Adams Beach, Madsen *1560, 1575, 1585, 1589.*

CYMOPOLIA BARBATA (L.) Lamx.—*Cuba.* Pinar del Río, Isla de Pinos: Playa de Bibijagua, Killip *41277.* Matanzas: Playa Varadera, Dawson *7790.*

DASYCLADUS VERMICULARIS (Scop.) Krasser.—*Florida.* Taylor Co.: Adams Beach, Madsen *1579. Cuba.* Pinar del Río: dredged at seven meters' depth off Cayo San Felipe, one plant almost 10 cm. tall, Bartsch *93E.*

BRYOPSIDACEAE

BRYOPSIS PENNATA Lamx.—*Cuba.* Pinar del Río: Puerto Esperanza, Dawson *7607.* Oriente: Bahía de Santiago, Dawson *7720.*

CAULERPACEAE

Caulerpa crassifolia (C. Ag.) J. Ag.—*Florida.* Manatee Co.: Piney Point. *Cuba.* Pinar del Río: Puerto Esperanza, Dawson *7590.* Camagüey: Tarafa, Dawson *7631.*

Caulerpa cupressoides (West) C. Ag.—*Florida.* Levy Co.: Cedar Key, Pierce *22.* *Cuba.* Pinar del Río: Puerto Esperanza, Dawson *7588.*

Caulerpa fastigiata Mont.—*Cuba.* Matanzas: Bahía Matanzas, Dawson *7749.* Camagüey: Tarafa, Dawson *7608.*

Caulerpa paspaloides (Bory) Grev. var. wurdemanni Weber-van Bosse.—*Florida.* Levy Co.: Cedar Key, Pierce *13.* *Cuba.* Dredged at seven meters' depth off the south coast, Bartsch *177B.*

Caulerpa prolifera (Forssk.) Lamx.—*Cuba.* Pinar del Río: Puerto Esperanza, Dawson *7587.*

Caulerpa racemosa (Forssk.) J. Ag.—*Cuba.* Camagüey: Tarafa, Dawson *7629.* Oriente: Bahía de Santiago, Dawson *7735;* Baitiquiri, Jervis *1357J.*

Caulerpa sertularioides (Gmel.) Howe.—*Cuba.* Pinar del Río: Puerto Esperanza, Dawson *7589.* Camagüey: Tarafa, Dawson, *7630.*

Caulerpa verticillata J. Ag.—*Cuba.* Pinar del Río: Puerto Esperanza, Dawson *7581.*

CODIACEAE

Avrainvillea nigricans Decaisne.—*Cuba.* Pinar del Río: dredged at seven meters' depth off Cayo San Felipe, Bartsch *93C.*

Boodleopsis pusillus (Coll. & Herv.) T., J. & B.—*Cuba.* Pinar del Río: Puerto Esperanza, Dawson *7573.*

Codium isthmocladum Vickers.—*Florida.* Franklin Co.: Wilsons Beach, Madsen *1031;* Alligator Point, Madsen *1587.* Levy Co.: Cedar Key, Pierce *4, 17.* *Cuba.* Matanzas: Bahía Matanzas, Dawson *7776.* Camagüey: Tarafa, Dawson *7626.*

Halimeda lacrimosa Howe.—*Cuba.* Pinar del Río: dredged at seven meters' depth off Cayo San Felipe, Bartsch *93L.*

Halimeda opuntia (L.) Lamx.—*Cuba.* Pinar del Río: Bahía Mariel, Dawson *7533;* Puerto Esperanza, Dawson *7592.*

Halimeda scabra Howe.—*Cuba.* Pinar del Río: dredged at seven meters' depth off Cayo San Felipe, Bartsch *93K.*

HALIMEDA TRIDENS (Ell. & Sol.) Lamx.—*Cuba.* Pinar del Río: Puerto Esperanza, Dawson *7593.*

HALIMEDA TUNA (Ell. & Sol.) Lamx.—*Cuba.* Oriente: Kittery Beach, Jervis *348*, *528.*

PENICILLUS CAPITATUS Lamx.—*Cuba.* Pinar del Río: Ensenada de Corrientes, Bartsch *57A;* dredged at four to nine meters' depth off Isla de Pinos, Bartsch *128D;* Bahía Mariel, Dawson *7534;* Puerto Esperanza, Dawson *7576.*

PENICILLUS DUMETOSUS (Lamx.) Blainv.—*Cuba.* Pinar del Río: dredged at seven meters' depth off Cayo San Felipe, Bartsch *93D;* dredged at four to nine meters' depth off Isla de Pinos, Bartsch *128C.*

PENICILLUS LAMOUROUXII Decaisne.—*Florida.* Levy Co.: Cedar Key, Pierce *1. Cuba.* Pinar del Río: Puerto Esperanza, Dawson *7578.*

RHIPOCEPHALUS PHOENIX (Ell. & Sol.) Kütz.—The plants recorded here represent peculiar forms of this species, with very light calcification, the filaments of the flabella being easily separated, although the flabellar association is evident. As to general outline, both forma *brevifolius* and forma *longifolius* of the species are approximated. The plants do not resemble *R oblongus* (Dec.) Kütz., in which the flabella are ill-developed The modification is, perhaps, in response to brackish water or high temperature in a shallow situation. *Cuba.* Pinar del Río: Puerto Esperanza, Dawson *7577*, *7577A.*

UDOTEA CONGLUTINATA (Ell. & Sol.) Lamx.—*Cuba.* Pinar del Río: dredged at seven meters' depth off Cayo San Felipe, Bartsch *93M.*

UDOTEA FLABELLUM (Ell. & Sol.) Howe.—*Cuba.* Pinar del Río: Puerto Esperanza, Dawson *7594.*

UDOTEA SPINULOSA Howe.—*Cuba.* Pinar del Río: dredged at seven meters' depth off Cayo San Felipe, Bartsch *93B.*

PHAEOPHYCEAE

ECTOCARPACEAE

ECTOCARPUS DASYCARPUS Kuckuck.—*Mississippi.* Harrison Co.: Biloxi, Drouet *9956.*

Ectocarpus duchassaignianus Grun.—*Florida.* Franklin Co.: Wilsons Beach, Madsen *1526.*

Ectocarpus mitchellae Harv.—*Florida.* Franklin Co.: Wilsons Beach, Madsen *1042.*

Ectocarpus siliculosus (Dillw.) Lyngb.—*Mississippi.* Hancock Co.: Waveland, Drouet *9833.* Harrison Co.: Biloxi, Drouet *10008.* Jackson Co.: Ocean Springs, Drouet *9886. Florida.* Franklin Co.: Ochlockonee Bay, Drouet *11723.* Levy Co.: Way Key, Drouet *11188.*

Pylaiella fulvescens (Schousb.) Born.—*Cuba.* Las Villas: Bahía Cienfuegos, Dawson *7661.*

SPHACELARIACEAE

Sphacelaria furcigera Kütz.—*Florida.* Levy Co.: Cedar Key, Drouet *11205.*

Sphacelaria tribuloides Menegh.—*Florida.* Bay Co.: Panama City, Drouet *10914.*

DICTYOTACEAE

Dictyopteris delicatula Lamx.—*Cuba.* Oriente: Bahía de Santiago, Dawson *7726;* Kittery Beach, Jervis *332*, *347*, *357.*

Dictyota bartayresii Lamx.—*Cuba.* Oriente: Kittery Beach, Jervis *361* (in part).

Dictyota cervicornis Kütz.—*Florida.* Lee Co.: Fort Myers, Crowson *978*, *979.*

Dictyota dentata (L.) Lamx.—*Cuba.* Oriente: Siboney, Dawson *7676;* Playa de Uvero, Jervis *933F*, *1758A;* Baitiquiri, Jervis *1357Q.*

Dictyota dichotoma (Huds.) Lamx.—*Cuba.* Pinar del Río: Bahía Mariel, Dawson *7518B.* Camagüey: Tarafa, Dawson *7638B.*

Dictyota divaricata Lamx.—*Cuba.* Oriente: Cable Beach, Jervis *527.*

Dilophus alternans J. Ag.—*Cuba.* Oriente: Siboney, Dawson *7675A;* Playa de Uvero, Jervis *9330.*

Dilophus guineensis (Kütz.) J. Ag.—*Cuba.* Oriente: Siboney, Dawson *7675B.*

Padina sp.—*Cuba.* Oriente: Cable Beach, Jervis *530*, *533*, *563*, and others. These specimens in part represent the plant described

by Collins, who considered it to be a new genus and species, as *Dictyerpa jamaicensis*. Sufficient material has come to hand from Cuba and Jamaica to demonstrate that Dictyerpa is a form variant of Padina. The stipes of the blades may initiate flagelliform, branching outgrowths which, by their continued growth, produce large, tangled masses. With age they commonly come loose from the object to which they were originally attached and appear to continue growth. On these masses branches quite frequently revert to form typical Padina blades. In one collection of plants from Jamaica these blades were fruiting and identified as *P. gymnospora*, but other species may perhaps on occasion develop the same habit.

Padina gymnospora (Kütz.) Vick.—*Cuba.* Camagüey: Tarafa, Dawson *7603.* Oriente: Bahía de Santiago, Dawson *7719;* Siboney, Dawson *7689;* Baitiquiri, Jervis *13571.*

Padina sanctae-crucis Børg.—*Cuba.* Pinar del Río: Bahía Mariel, Dawson *7529.*

Padina vickersiae Hoyt.—*Florida.* Levy Co.: Cedar Key, Pierce *12, 16. Cuba.* Las Villas: Bahía Cienfuegos, Sparrow.

Pocockiella variegata (Lamx.) Papenf.—*Cuba.* Pinar del Río: Bahía Mariel, Dawson *7550.* Oriente: Cable Beach, Jervis *529;* Kittery Beach, Jervis *359.*

Zonaria zonalis (Lamx.) Howe.—*Cuba.* Oriente: Playa de Uvero, Jervis *933D;* Cable Beach, Jervis *522, 523;* Kittery Beach, Jervis *363, 375,* and others.

CHORDARIACEAE

Aegira zosterae (Mohr) Fries.—*Florida.* Bay Co.: St. Andrews Bay, Madsen *1572.* Lee Co.: Sanibel I., Lewin.

STILOPHORACEAE

Stilophora rhizoides (Ehrh.) J. Ag.—*Florida.* Levy Co.: Cedar Key, Drouet *11201.*

SPOROCHNACEAE

Sporochnus pedunculatus (Huds.) C. Ag.—*Florida.* Franklin Co.: Alligator Point, Madsen *1538, 1545.* Taylor Co.: Adams Beach, Madsen *1581.*

ASPEROCOCCACEAE

COLPOMENIA SINUOSA (Roth) Derb. & Sol.—*Cuba.* Oriente: Siboney, Dawson *7669.*

SCYTOSIPHON LOMENTARIA (Lyngb.) C. Ag.—*Florida.* Franklin Co.: Carrabelle, Drouet *11705.* Wakulla Co.: St. Marks River, Drouet *11786.*

SARGASSACEAE

SARGASSUM FILIPENDULA C. Ag.—*Florida.* Escambia Co.: Gulf Beach, Drouet *10623.*

SARGASSUM FILIPENDULA near var. MONTAGNEI (Bail.) Coll. & Herv.—The plants listed here seem to be intermediate between the typical species and the extreme aspect of the variety. *Florida.* Franklin Co.: Wilsons Beach, Madsen *1533;* Carrabelle, Drouet *11698, 11706;* New River, Drouet *11716.* Lee Co.: Fort Myers, Crowson *988.*

SARGASSUM FLUITANS Børg.—*Louisiana.* Jefferson Parish: Grand Isle, Drouet *9500;* Chenier Caminada, Drouet *9475B. Florida.* Escambia Co.: Gulf Beach, Drouet *10623. Cuba.* Pinar del Río, Isla de Pinos: Playa de Bibijagua, Killip *41276.*

SARGASSUM HYSTRIX J. Ag., near var. BUXIFOLIUM (Chauv.) J. Ag.—*Florida.* Escambia Co.: Gulf Beach, Drouet *10623B.*

SARGASSUM LINIFOLIUM (Turn.) C. Ag.?—*Louisiana.* Jefferson Parish: Chenier Caminada, Drouet *9475C. Florida.* Escambia Co.: Gulf Beach, Drouet *10623* (in part). Bay Co.: St. Andrews, Drouet *10939.* Levy Co.: Way Key, Drouet *11195, 11302A.*

SARGASSUM NATANS (L.) J. Meyen.—*Louisiana.* Jefferson Parish: Grand Isle, Drouet *9500. Cuba.* Matanzas: Bahía Matanzas, Dawson *7771.* Las Villas: Bahía Cienfuegos, Sparrow. Oriente: Baitiquiri, Jervis *1357N;* Cable Beach, Jervis *303;* Kittery Beach, Jervis *368.*

SARGASSUM PLATYCARPUM Mont.—*Cuba.* Pinar del Río: Ensenada de Corrientes, Bartsch *57D.* Oriente: Playa de Uvero, Jervis *933K.*

SARGASSUM POLYCERATIUM Mont.—*Cuba.* Camagüey: Tarafa, Dawson *7632.* Oriente: Kittery Beach, Jervis *372.*

SARGASSUM PTEROPLEURON Grun.—*Florida.* Levy Co.: Cedar Key, Pierce. *Cuba.* Pinar del Río, Isla de Pinos: Playa Nueva Gerona, Killip *41650.*

Sargassum rigidulum Kütz.—*Cuba.* Oriente: Cable Beach, Jervis *567.*

Sargassum vulgare C. Ag.—*Cuba.* Pinar del Río, Isla de Pinos: Playa Columpo, Killip *41677.* Oriente: Kittery Beach, Jervis *369, 371, 373.*

Sargassum vulgare var. foliosissimum (Lamx.) J. Ag.—*Louisiana.* Jefferson Parish: Chenier Caminada, Drouet *947A;* Grand Isle, Drouet *9500. Cuba.* Oriente: Playa Escondido, Jervis *579;* Kittery Beach, Jervis *370.*

Turbinaria tricostata Bert.—*Cuba.* Oriente: Siboney, Dawson *7688;* Baitiquiri, Jervis *1357D;* Kittery Beach, Jervis *362, 366.*

Turbinaria turbinata (L.) Kuntze.—*Cuba.* Pinar del Río, Isla de Pinos: Playa Nueva Gerona, Killip *41651.* Las Villas: Bahía Cienfuegos, Sparrow. Oriente: Playa de Uvero, Jervis *933N;* Baitiquiri, Jervis *1357C;* Cable Beach, Jervis *302, 399, 566.*

RHODOPHYCEAE

BANGIACEAE

Goniotrichum alsidii (Zanard.) Howe.—*Cuba.* Pinar del Río: Puerto Esperanza, Dawson *7569A, 7601A.*

COMPSOPOGONACEAE

Compsopogon coeruleus (Balbis) Mont.—Identifications on a sound basis in the genus Compsopogon are hardly possible for American plants. There has been no modern, critical review of the genus. These plants are found in tidal streams of the Gulf Coast and in brackish water along the shore. *Louisiana.* Lafourche Parish: Leeville, Drouet *9438.* Orleans Parish: Lake Pontchartrain, Drouet *9336. Florida.* Franklin Co.: Apalachicola Bay, *11693.*

CHAETANGIACEAE

Galaxaura cylindrica (Ell. & Sol.) Lamx.—*Cuba.* Oriente: Kittery Bay, Jervis *378, 382, 383.*

Galaxaura flagelliformis Kjellm.—*Cuba.* Pinar del Río: Bahía Mariel, Dawson *7536A.*

Galaxaura lapidescens (Ell. & Sol.) Lamx.—*Cuba.* Pinar del Río: Bahía Mariel, Dawson *7537B, 7539.*

Galaxaura rugosa (Ell. & Sol.) Lamx.—*Cuba.* Las Villas: Bahía

Cienfuegos, Sparrow. Oriente: Kittery Beach, Jervis *377*, *380*, *384*, *385*, *386*.

Galaxaura squalida Kjellm.—*Cuba*. Pinar del Río: Bahía Mariel, Dawson *7536B*, *7536C*, *7537C*. Camagüey: Tarafa, Dawson *7647*. Oriente: Kittery Beach, Jervis *338*, *379*, *381*.

Galaxaura subverticillata Kjellm.—*Cuba*. Pinar del Río: Bahía Mariel, Dawson *7537D*.

Scinaia complanata (Coll.) Cott.—*Florida*. Franklin Co.: Alligator Point, Madsen *1055*.

GELIDIACEAE

Gelidiella acerosa (Forssk.) Feldm. & Hamel—*Cuba*. Oriente: Siboney, Dawson *7707;* Kittery Beach, Jervis *353*.

Gelidium crinale (Turn.) Lamx. var. platycladum Taylor.—*Florida*. Okaloosa Co.: Santa Rosa I., Drouet *10729*.

Gelidium pusillum (Stackh.) LeJolis.—*Florida*. Levy Co.: Way Key, Drouet *11176*. *Cuba*. Las Villas: Bahía Cienfuegos, Sparrow. Oriente: Kittery Beach, Jervis *360*.

RHIZOPHYLLIDACEAE

Ochtodes secundiramea (Mont.) Howe.—*Cuba*. Oriente: Bahía de Santiago, Dawson *7724;* Siboney, Dawson *7700;* Kittery Beach, Jervis *349*, *354*.

CORALLINACEAE

Amphiroa fragilissima (L.) Lamx.—*Cuba*. Oriente: Kittery Beach, Jervis *335*, *345*, *356*.

Corallina cubensis (Mont.) Kütz.—*Cuba*. Matanzas: Bahía Matanzas, Dawson *7748*.

Fosliella farinosa (Lamx.) Howe.—*Florida*. Gulf Co.: Port St. Joe, Drouet *10944* (in part), *11688*. Levy Co.: Cedar Key, Drouet *11120A*. *Cuba*. Pinar del Río: Bahía Mariel, Dawson *7523*. Habana: Batabanó, Dawson *7563* (in part).

Fosliella lejolisii (Rosanoff) Howe.—*Florida*. Gulf Co.; Port St. Joe, Drouet *10944* (in part).

Jania capillacea Harv.—*Florida*. Escambia Co.: Gulf Beach, Drouet *10623B*.

GRATELOUPIACEAE

Grateloupia filicina (Wulf.) C. Ag.—*Cuba*. Matanzas: Bahía Matanzas, Dawson *7745*.

HALYMENIA PSEUDOFLORESIA Coll. & Howe.—*Florida.* Franklin Co.: Alligator Point, Madsen *1056, 1586.*

SOLIERIACEAE

AGARDHIELLA TENERA (J. Ag.) Schm.—*Florida.* Franklin Co.: Alligator Point, Madsen *1064;* Carrabelle, Drouet *11013A.* Lee Co.: Fort Myers, Crowson *980. Cuba.* Matanzas: Bahía Matanzas, Dawson *7753.*

RHABDONIA RAMOSISSIMA (Harv.) J. Ag.—*Florida.* Levy Co.: Cedar Key, Pierce *2, 14.*

HYPNEACEAE

HYPNEA CERVICORNIS J. Ag.—*Florida.* Levy Co.: Cedar Key, Pierce *19.* Pinellas Co.: St. Petersburg, Harris *1501B.* Lee Co.: Fort Myers, Crowson *981. Cuba.* Oriente: Cable Beach, Jervis *308.*

HYPNEA CORNUTA (Lamx.) J. Ag.—*Cuba.* Pinar del Río: Bahía Mariel, Dawson *7541.* Camagüey: Tarafa, Dawson *7619.*

HYPNEA MUSCIFORMIS (Wulf.) Lamx.—*Florida.* Franklin Co.: Wilsons Beach, Madsen *1034C, 1035, 1527.* Pinellas Co.: St. Petersburg, Harris *1510A.* Manatee Co.: Piney Point, Lewin. Lee Co.: Fort Myers, Crowson *984A;* Sanibel I., Lewin. *Cuba.* Pinar del Río: Bahía Mariel, Dawson *7527, 7540.* Habana: Playa Marianao, Killip *41604.* Matanzas: Bahía Matanzas, Dawson *7775.* Las Villas: Bahía Cienfuegos, Sparrow. Camagüey: Tarafa, Dawson *7635.* Oriente: Bahía de Santiago, Dawson *7711, 7712;* Playa de Verracco, Jervis *1889;* Playa de Uvero, Jervis *1758B;* Baitiquiri, Jervis *1357G.*

GRACILARIACEAE

GRACILARIA CONFERVOIDES (Roth) LeJol.—*Florida.* Franklin Co.: Eastpoint, Madsen *1552;* Alligator Point, Madsen *1061B, 1541;* Wilsons Beach, Madsen *1033, 1039, 1525.* Levy Co.: Cedar Key, Pierce *5;* Way Key, Drouet *11196.* Manatee Co.: Piney Point, Lewin. Lee Co.: Fort Myers, Crowson *990. Cuba.* Matanzas: Bahía Matanzas, Dawson *7738.* Las Villas: Bahía Cienfuegos, Dawson *7656A.* Camagüey: Tarafa, Dawson *7634.* Oriente: Bahía de Santiago, Dawson *7714A.*

GRACILARIA FEROX J. Ag.—*Florida.* Franklin Co.: Alligator Point, Madsen *1536C. Cuba.* Camagüey: Tarafa, Dawson *7636.*

GRACILARIA FOLIIFERA (Forssk.) Børg.—*Cuba.* Matanzas: Bahía

Matanzas, Dawson *7752B*. Las Villas: Bahía Cienfuegos, Dawson *7675B*. Oriente: Bahía de Santiago, Dawson *7714B*, *7736*.

Gracilaria mamillaris (Mont.) Howe.—*Cuba*. Matanzas: Bahía Matanzas, Dawson *7770*.

GIGARTINACEAE

Gigartina acicularis (Wulf.) Lamx.—*Cuba*. Las Villas: Bahía Cienfuegos, Sparrow. Matanzas: Bahía Matanzas, Dawson *7744*.

CHAMPIACEAE

Champia parvula (C. Ag.) Harv.—*Florida*. Levy Co.: Cedar Key, Drouet *11201*. Bay Co.: St. Andrews Bay, Drouet *11430A*. Gulf Co.: Port St. Joe, Drouet *11691*. Franklin Co.: Carrabelle, Drouet *11703*, *11709;* Wilsons Beach, Madsen *1041;* Alligator Point, Madsen *1052*.

Lomentaria baileyana (Harv.) Farl.—*Florida*. Gulf Co.: Port St. Joe, Drouet *11690*. Lee Co.: Fort Myers, Crowson *992*.

CERAMIACEAE

Centroceras clavulatum Mont.—*Cuba*. Pinar del Río: Puerto Esperanza, Dawson *7572*. Matanzas: Bahía Matanzas, Dawson *7760*. Camagüey: Tarafa, Dawson *7643*. Oriente: Siboney, Dawson *7690;* Playa de Uvero, Jervis *933E*.

Ceramium byssoideum Harv.—*Florida*. Franklin Co.: Wilsons Beach, Madsen *1029*. *Cuba*. Matanzas: Bahía Matanzas, Dawson *7741*.

Ceramium fastigiatum Harv., var. flaccidum Petersen.—*Florida*. Franklin Co.: Alligator Point, Madsen *1538*. *Cuba*. Matanzas: Bahía Matanzas, Dawson *7739*. Camagüey: Tarafa, Dawson *7641*. Oriente: Siboney, Dawson *7683*.

Ceramium nitens (C. Ag.) J. Ag.—*Cuba*. Matanzas: Bahía Matanzas, Dawson *7754*. Camagüey: Tarafa, Dawson *7604*. Oriente: Playa de Uvero, Jervis *933G*.

Ceramium subtile J. Ag.—*Florida*. Bay Co.: Sunnyside, Madsen *1502*. *Cuba*. Las Villas: Bahía Cienfuegos, Sparrow. Camagüey: Tarafa, Dawson *7642*.

Ceramium tenuissimum (Lyngb.) J. Ag.—*Florida*. Santa Rosa Co.: Santa Rosa Sound, Drouet *10626*.

CROUANIA ATTENUATA (Bonnem.) J. Ag.—*Cuba.* Pinar del Río: Bahía Mariel, Dawson *7545.*

GRIFFITHSIA TENUIS C. Ag.—*Florida.* Santa Rosa Co.: Santa Rosa Sound, Drouet *10628A.*

GYMNOTHAMNION ELEGANS (Schousb.) J. Ag.—*Cuba.* Matanzas: Bahía Matanzas, Dawson *7789* (in minor part).

SPYRIDIA FILAMENTOSA (Wulf.) Harv.—*Florida.* Gulf Co.: St. Joseph Bay, Drouet *11692.* Franklin Co.: St. Georges Sound, Drouet *11704, 11714.* Manatee Co.: Piney Point, Lewin. Lee Co.: Fort Myers, Crowson *991. Cuba.* Pinar del Río: Bahía Mariel, Dawson *7531, 7532;* Puerto Esperanza, Dawson *7565.* Las Villas: Bahía Cienfuegos, Sparrow. Habana: Batabanó, Dawson *7554.* Camagüey: Tarafa, Dawson *7644.* Oriente: Siboney, Dawson *7679;* Baitiquiri, Jervis *1357F.*

DELESSERIACEAE

CALOGLOSSA LEPRIEURII (Mont.) J. Ag. (det. F. Drouet).—*Florida.* Levy Co.: Cedar Key, Drouet *11137;* Way Key, Drouet *11159.* Escambia Co.: Pensacola, Drouet *10615.* Bay Co.: West Bay, Drouet *10862.* Franklin Co.: Apalachicola, Drouet *11656.* Wakulla Co.: Port Leon, Drouet *11466.*

DASYACEAE

DASYA PEDICELLATA (C. Ag.) C. Ag.—*Florida.* Franklin Co.: Alligator Point, Madsen *1050,* Drouet *11720.* Wakulla Co.: St. Marks, Drouet *11789A.* Lee Co.: Fort Myers, Crowson *985,* Lewin.

HETEROSIPHONIA GIBBESII (HARV.) Falk.—*Cuba.* Pinar del Río: Puerto Esperanza, Dawson *7582.* Habana: Batabanó, Dawson *7553.*

HETEROSIPHONIA WURDEMANNI (Bail.) Falk.—*Florida.* Franklin Co.: Wilsons Beach, Madsen *1036.*

RHODOMELACEAE

ACANTHOPHORA SPICIFERA (Vahl) Børg.—*Florida.* Lee Co.: Fort Myers, Crowson *984B. Cuba.* Pinar del Río: Bahía Mariel, Dawson *7525;* Puerto Esperanza, Dawson *7567.* Camagüey: Tarafa, Dawson *7609.* Oriente: Playa de Uvero, Jervis *933B;* Baitiquiri, Jervis *1357H.*

Amansia multifida Lamx.—*Cuba.* Oriente: Playa de Uvero, Jervis *1357R.*

Bostrychia binderi Harv.—*Florida.* Levy Co.: Cedar Key, Drouet *11145. Cuba.* Oriente: Cable Beach, Jervis *703A.*

Bostrychia montagnei Harv.—*Florida.* Collier Co.: Marco I., Standley *92830.*

Bostrychia moritziana C. Ag.—*Louisiana.* Orleans Parish: Lake Pontchartrain, Drouet *9319. Florida.* Bay Co.: West Bay, Drouet *10865, 10879.* Franklin Co.: Eastpoint, Drouet *10955;* Carrabelle, Drouet *11677.* Wakulla Co.: St. Marks, Drouet *11740.*

Bostrychia radicans Mont.—*Louisiana.* Jefferson Parish: Chenier Caminada, Drouet *9476, 9497. Mississippi.* Hancock Co.: Waveland, Drouet *9805, 9807, 9811, 9821, 9834;* St. Louis Bay, Drouet *9836, 9863.* Harrison Co.: Back Bay, Drouet *10030.* Jackson Co.: Ocean Springs, Drouet *9904, 9905, 9906. Florida.* Franklin Co.: Eastpoint, Drouet *11695;* Carrabelle, Drouet *11008A, 11713;* New River, Drouet *10948;* Alligator Point, Madsen *1044.* Wakulla Co.: Port Leon, Drouet *11463, 11467.* Taylor Co.: Steinhatchee River, Drouet *11235, 11239;* Daughter Creek, Drouet *11218.* Levy Co.: Way Key, Drouet *11165; 11181, 11184;* Cedar Key, Drouet *11114, 11123, 11143.*

Bostrychia tenella (Vahl) J. Ag.—*Cuba.* Oriente: Siboney, Dawson *7693.*

Brongniartella mucronata (Harv.) Schm.—*Florida.* Franklin Co.: Alligator Point, Madsen *1537.*

Bryocladia cuspidata (J. Ag.) DeToni.—*Cuba.* Matanzas: Bahía Matanzas, Dawson *7740.*

Bryothamnion seaforthii (Turn.) J. Ag.—*Cuba.* Pinar del Río, Isla de Pinos: Playa Nueva Gerona, Killip *41647.* Matanzas: Bahía Matanzas, Dawson *7757, 7758A.*

Bryothamnion triquetrum (Gmel.) Howe.—*Cuba.* Matanzas: Bahía Matanzas, Dawson *7758B, 7758C;* Playa de Uvero, Jervis *933A;* Baitiquiri, Jervis *1357K.*

Chondria atropurpurea Harv.—*Florida.* Franklin Co.: Alligator Point, Madsen *1061C, 1534.*

Chondria cnicophylla (Melv.) DeToni.—*Florida.* Santa Rosa Co.: Santa Rosa Sound, Drouet *10629.* Okaloosa Co.: Santa Rosa I., Drouet *10730.* Bay Co.: St. Andrews, Madsen *1567, 1574.* Levy Co.: Cedar Keys (type locality of Melvill, in Murray, 1888, p.

333, pl. 284, as Chondriopsis), Pierce *20*. Wakulla Co.: East River, Drouet *11780*. Taylor Co.: Adams Beach, Madsen *1588*, *1593*.

Chondria floridana (Coll.) Howe.—*Florida*. Levy Co.: Cedar Key, Pierce.

Chondria leptacremon (Melv.), comb. nov.—*Chondria sp.*, Melvill, 1875. *Chondriopsis leptacremon* Melvill in Murray, 1888, p. 333, pl. 284, figs. 2 a–b. Type from Key West, Florida. *Florida*. Bay Co.: Sunnyside, Madsen *1509*.

Chondria littoralis Harv.—*Florida*. Franklin Co.: Carrabelle, Drouet *11710;* Alligator Point, Drouet *11721;* Madsen *1536*.

Chondria tenuissima (G. & W.) C. Ag.—*Florida*. Franklin Co.: Wilsons Beach, Madsen *1520*, *1522*. Lee Co.: Fort Myers, Lewin. *Cuba*. Matanzas: Playa Varadera, Dawson *7791*.

Digenia simplex (Wulf.) C. Ag.—*Florida*. Santa Rosa Co.: Santa Rosa Sound, Drouet *10624*. Levy Co.: Cedar Key, Pierce; Way Key, Drouet *11194*. *Cuba*. Pinar del Río: dredged at seven meters' depth off Cayo San Felipe, Bartsch *93F;* Bahía Mariel, Dawson *7530;* Isla de Pinos, Playa Columpo, Killip *41676*. Camagüey: Tarafa, Dawson *7614*. Oriente: Siboney, Dawson *7666*.

Laurencia gemmifera Harv.—*Florida*. Santa Rosa Co.: Santa Rosa Sound, Drouet *10625*. Bay Co.: Sunnyside, Madsen *1508*. Gulf Co.: St. Joseph Bay, Drouet *11692A*. Franklin Co.: Ochlockonee Bay, Drouet *11722;* Wilsons Beach, Madsen *1032*. Taylor Co.: Adams Beach, Madsen *1590*. *Cuba*. Pinar del Río: Puerto Esperanza, Dawson *7585;* dredged at seven meters' depth off Cayo San Felipe, Bartsch *73G*.

Laurencia intricata Lamx.—*Florida*. Franklin Co.: Wilsons Beach, Madsen *1034*, *1517*. Levy Co.: Cedar Key, Pierce *7*. *Cuba*. Pinar del Río, Isla de Pinos: Playa Columpo, Killip *41675*.

Laurencia microcladia Kütz.—*Cuba*. Oriente: Cable Beach, Jervis *534*, *540*, *557*, *564*.

Laurencia obtusa (Huds.) Lamx.—*Florida*. Franklin Co.: Alligator Point, Madsen *1537*, *1544*. Taylor Co.: Adams Beach, Madsen *1590*. *Cuba*. Pinar del Río, Isla de Pinos: Playa Nueva Gerona, Killip *41642*. Oriente: Bahía de Santiago, Dawson *7715;* Bahía Escondido, Jervis *577;* Playa de Uvero, Jervis *933C*.

Laurencia papillosa (Forssk.) Grev.—*Cuba*. Pinar del Río: Bahía Mariel, Dawson *7517*. Matanzas: Bahía Matanzas, Dawson *7780*. Las Villas: Bahía Cienfuegos, Sparrow, Dawson *7664*. Camagüey:

Tarafa, Dawson *7628*. Oriente: Baitiquiri, Jervis *1357L;* Cable Beach, Jervis *531, 551, 555, 560.*

MURRAYELLA PERICLADOS (C. Ag.) Schm.—*Cuba.* Habana: Batabanó, Dawson *7552.*

POLYSIPHONIA RAMENTACEA Harv.—*Florida.* Santa Rosa Co.: Pensacola Beach, Drouet *10604, 10628.* Bay Co.: St. Andrews Bay, Madsen *1568, 1573;* Drouet *11433;* Panama City, Drouet *11431.* Taylor Co.: Adams Beach, Madsen *1556, 1561, 1576, 1583, 1588.*

POLYSIPHONIA SUBTILISSIMA Mont.—*Louisiana.* Orleans Parish: Lake Pontchartrain and marshes southwest, Drouet *9318, 9333, 9335. Mississippi.* Hancock Co.: Waveland, Drouet *9831. Florida.* Wakulla Co.: Port Leon, Drouet *11465.*

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FORESTRY

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A LABORATORY STUDY OF VARIOUS SYSTEMATIC SAMPLING METHODS APPLICABLE TO FOREST-REGENERATION SURVEYS*

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Introduction

TREE reproduction on any tract of forest land is of considerable importance to both the owner and the manager. The quantity, quality, and distribution of this reproduction determine to a large extent the value of the stand, as well as the amount of silvicultural work required to keep the land productive.

Foresters are generally dependent on rapid, inexpensive sampling methods for quantitative and qualitative estimates of tree regeneration. Their task is complicated by the heterogeneous character of tree-reproduction patterns, the wide range in the number of individuals of the various species found on most tracts, and the large size of the forested areas. At present most estimates are based on samples which cover less than one per cent of the area in question. For this reason the sample plots are generally selected according to a system, or pattern, rather than at random, in order to assure their even distribution.

Unfortunately, the various possible methods of systematic sampling aimed at reliable estimates of forest reproduction for management purposes have not been fully explored. Ecologists, to be sure, have developed sampling procedures that appear to be fairly satisfactory for estimating vegetative densities and frequencies on small tracts, but these are too detailed and too expensive for use in forest management (many of the *principles* have definite application, however).

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Few forestry publications or silvicultural textbooks, moreover, discuss sampling techniques applicable to forest regeneration, though mensuration texts give considerable space to sampling methods for estimating timber volumes. The proper size and arrangement of sample plots, their distribution, and the intensity of sampling necessary for estimates of tree reproduction are consequently debatable subjects among foresters.

The present paper reports on the reliability of estimates that were obtained from applying different systematic sampling methods that might possibly have use in forest-reproduction surveys to one artificially created seed pattern of known distribution. Since in nature tree seedlings often occur in patches and are at best rather unevenly distributed, a knowledge of the number per acre is often not so useful to the forester as a knowledge of the distribution of the seedlings over the whole area. However, estimates of tree reproduction in actual number of seedlings per acre may have considerable use in the evaluation of silvicultural practices. As will be seen, although no particular method tried in our study was found to be very reliable for estimating quantities of seedlings when 4 per cent or less of the area was sampled, one or two of the methods nonetheless appear to be more practical and less costly than the others—but just as reliable—for possible use in forest-reproduction surveys. Sampling intensities of less than 4 per cent, however, seem to be fairly reliable for estimating the percentage of stocked plots.

The Study

It is almost impossible to count and map all the tree seedlings on a forest tract even as small as one acre, not to mention one of five or ten acres, in order to have a known quantity and a known distribution for appraising the reliability of different methods and intensities of sampling. However, the natural distribution of tree seedlings in varying numbers per unit of area may be simulated in the laboratory in a way that will be representative of many natural conditions in the field.

In this study 4,000 squares of equal size (about one inch on a side) were plotted on a rectangular chart approximately 4 × 7 feet, with 50 squares running one way and 80 the other. If each square is taken to represent a forest plot one milacre in size (1/1,000 of an acre—the size of plot commonly used in reproduction surveys), the 4,000-square chart would typify a sample area of four acres. Several

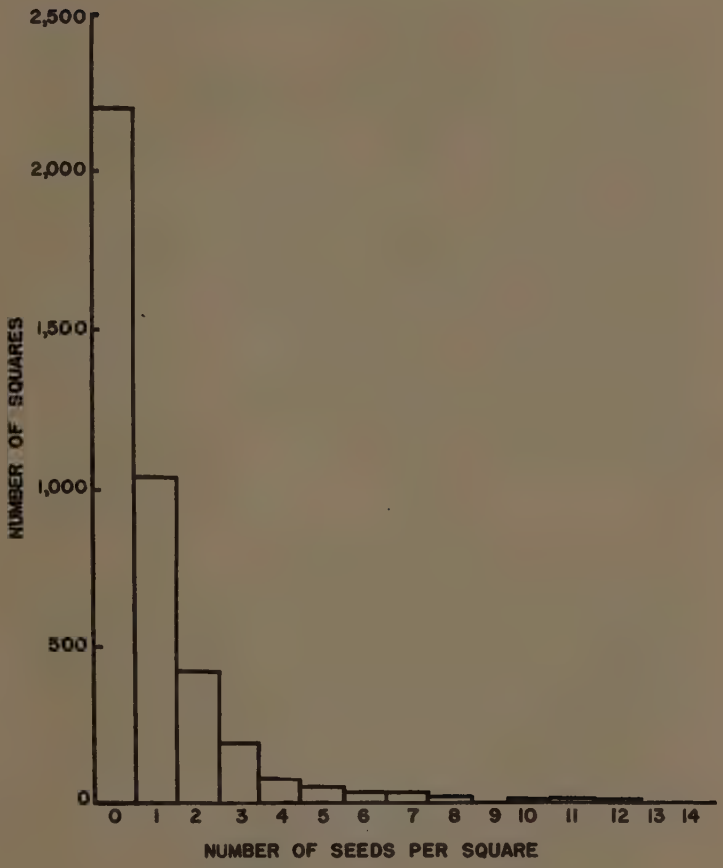

FIG. 1. Frequency distribution of seeds over entire test area

handfuls of flax seeds were next thrown into the air above the chart. (Flax seeds were used because they do not roll easily.) The location of each seed that came to rest on the chart was marked, and the seeds were removed.

A total of 3,300 seeds fell on the chart, or 825 per thousand squares. The number of seeds per square, or quadrat, is diagrammed in Figure 1. There were 2,204 squares, or 55 per cent, with no seeds and

1,025 squares, or 25.6 per cent, with only one seed. The maximum number of seeds on any one square was 14. In all, 45 per cent of the squares contained one or more seeds. The frequency distribution presented in Figure 1 is not a Poisson distribution, which indicates that perhaps the seeds were not thrown so randomly as we assumed.

It was first planned to sample one model area with a relatively uniform seed-distribution pattern and then, having scattered over this area imaginary roads and other features which would provide large blank spaces where no reproduction would take place, to sample the resulting distribution pattern by some of the methods that showed in our tests the most promise of being fairly reliable in estimating the quantity of seeds. However, because of the difficulty experienced in obtaining accurate quantity estimates with a sampling intensity of 4 per cent of the area or less in tests where the dispersal of the seeds was rather uniform, no other distribution patterns were sampled.

Sampling Designs Tested

estimates of quantity

A total of twenty-five different systematic sampling methods which might be used in regeneration surveys were tested to estimate the number of seeds on the chart by counting the number on each sample plot. Both 2 per cent and 4 per cent of the area were sampled fifty times by each method in order to estimate the quantity of seeds and to determine the number of estimates that fell within various limits of accuracy. The twenty-five methods used, and the results, are shown in Table I.

estimates of stocking

The number of plots on the sample area stocked with one or more seeds was estimated by means of fourteen of the twenty-five sampling methods, based on yielding 1, 2, and 4 per cent samples; the methods used (numbered according to their appearance in Table I) were: 1, 4, 5, 6, 13, 15, 16, 17, 18, 19, 20, 21, 23, and 24. The results, showing the number of estimates falling within ± 5 per cent of the actual percentage of stocking and the range of the estimates obtained by each of these methods are presented in Table II. Each sampling design was repeated twenty-five times to determine the number of estimates falling within various limits of accuracy.

Discussion of Results

ESTIMATES OF TOTAL NUMBER OF SEEDS

The seed-distribution pattern being sampled was rather uniform even though 55 per cent of the plots were blank. There were no large blocks of plots containing no seeds—a condition which normally complicates sampling to estimate the total number per unit of area. Nevertheless, most of the quantity estimates obtained, regardless of the sampling method employed, were rather unreliable when only 2 per cent and 4 per cent of the area were sampled. The percentages of the fifty estimates falling within a range of ± 5, ± 10, ± 15, and ± 20 per cent of the actual number of seeds are presented in Table I.

For the single continuous-strip method (No. 1), only eleven of the fifty estimates, or 22 per cent, were within 10 per cent of the actual number of seeds. If within ± 20 per cent of accuracy is considered sufficient, only 44 per cent of the estimates were within this range of the actual number. Moreover, doubling the sample by measuring two continuous strips across the area increased the reliability of the estimates only slightly.

The sampling designs that resulted in the most reliable estimates were those having the most dispersed distribution of the individual plots. This exemplifies a fundamental statistical concept already established in other sampling work. But although a systematic dispersal of small plots uniformly over the area to be studied may result in the most reliable estimate for the intensity of the sample, this is also generally the most expensive method of sampling because of the numerous trips required through the tract.

The most reliable estimates were obtained with method No. 10, which sampled every fourth plot on parallel strips. However, this method required four trips across the area for a 2 per cent sample and eight trips for a 4 per cent sample. In all probability the more dependable figure obtained by this method is related to chance or to the particular distribution pattern of the seed population rather than to the sampling design itself. Sampling every fifth, eighth, and tenth plot, which require correspondingly more trips across the area for the same intensity of sample, did not materially increase the reliability of the estimates.

The sampling design which resulted in the most reliable estimates for a given number of trips across the area was an arrangement of plots in a diagonal direction across the sample area. Series of 10

TABLE I

RELIABILITY OF TWENTY-FIVE SAMPLING METHODS USED TO ESTIMATE THE TOTAL NUMBER OF SEEDS ON AN AREA

Sampling method	Percentage of area sampled	No. of trips across area	Percentage of 50 estimates accurate within a range of			
			±5%	±10%	±15%	±20%
1. Lengthwise* strips of 80 continuous plots	2	1	12	22	30	44
	4	2	10	28	36	58
2. Lengthwise strips of 40 continuous plots, parallel and equally spaced	2	2	18	36	48	54
	4	4	18	42	48	60
3. Crosswise* strips of 40 continuous plots, parallel and equally spaced	2	2	18	28	42	58
	4	4	30	52	62	82
4. Strips of 20 continuous plots, parallel and equally spaced	2	2	14	24	32	44
	4	4	14	26	44	62
5. Strips of 10 continuous plots, parallel and equally spaced	2	2	16	32	44	52
	4	4	12	38	64	72
6. Strips of 5 continuous plots, parallel and equally spaced	2	2	18	26	32	44
	4	4	20	46	58	74
7. Strips of 4 continuous plots, parallel and equally spaced	2	4	10	18	34	46
	4	8	20	42	54	66
8. Every second plot on parallel strips	2	2	18	24	42	52
	4	4	24	40	58	88
9. Every third plot on parallel strips	2	4	18	30	52	64
	4	8	20	52	62	78
10. Every fourth plot on parallel strips	2	4	30	56	74	82
	4	8	48	82	88	94
11. Every fifth plot on parallel strips	2	5	24	32	44	66
	4	10	32	56	68	80
12. Every eighth plot on parallel strips	2	8	20	44	56	84
	4	16	30	60	74	94
13. Every tenth plot on parallel strips	2	10	24	38	60	76
	4	20	22	58	76	92
14. Every second set of two continuous plots, parallel and equally spaced	2	2	4	14	34	46
	4	4	24	34	54	62
15. Four contiguous plots in a square, parallel and equally spaced	2	2	12	26	36	52
	4	4	18	32	50	66

*"Lengthwise" is the direction having 80 continuous plots; "crosswise" is the direction having 50 continuous plots. One continuous strip of 80 plots is equivalent to a 2 per cent sample; 2 such strips, in parallel, are equivalent to a 4 per cent sample.

TABLE I (*continued*)

Sampling method	Percentage of area sampled	No. of trips across area	Percentage of 50 estimates accurate within a range of			
			±5%	±10%	±15%	±20%
16. Five contiguous plots in L arrangement, parallel and equally spaced	2	2	20	30	46	68
	4	4	18	30	46	68
17. Ten contiguous plots in a rectangle (2 × 5 plot arrangement) lengthwise of the area, parallel and equally spaced	2	1	4	14	22	32
	4	2	10	14	30	40
18. Ten contiguous plots in a rectangle (2 × 5 plot arrangement) crosswise of the area, parallel and equally spaced	2	2	12	26	42	64
	4	4	38	54	70	78
19. Twenty contiguous plots in a rectangle (2 × 10 plot arrangement), parallel and equally spaced	2	1	18	28	30	42
	4	2	12	36	44	56
20. Twenty contiguous plots in a rectangle (4 × 5 plot arrangement), parallel and equally spaced	2	2	12	24	34	42
	4	4	28	40	52	60
21. Twenty contiguous plots in a rectangle (5 × 4 plot arrangement), parallel and equally spaced	2	1	8	20	32	50
	4	2	10	18	30	46
22. Series of 10 continuous plots, offset at equal intervals on a diagonal, lengthwise of the area	2	1	18	28	46	66
	4	2	18	44	58	68
23. Series of 10 continuous plots, offset at equal intervals on a diagonal, crosswise of the area	2	2	10	26	38	50
	4	4	24	42	60	74
24. Series of 5 continuous plots, offset at equal intervals on a diagonal, lengthwise of the area	2	1	18	34	46	60
	4	2	28	54	64	80
25. Series of 5 continuous plots, offset at equal intervals on a diagonal, crosswise of the area	2	2	8	20	42	58
	4	4	28	46	66	86

continuous plots offset at equal intervals in a diagonal direction across the tract yielded, in a 2 per cent sampling, estimates of which two thirds were within 20 per cent of the actual number. This method required only one trip across the area. Doubling the sample (two trips) increased the reliability of the estimates only slightly. A similar method (No. 24), consisting of series of 5 continuous plots offset at equal intervals diagonally across the tract also gave estimates of which about 60 per cent fell within 20 per cent of accuracy. Doubling the sample for this design (two trips) increased the number of estimates that were within 20 per cent of accuracy to 80 per cent.

TABLE II

RELIABILITY OF FOURTEEN SAMPLING METHODS USED TO ESTIMATE THE NUMBER OF PLOTS STOCKED WITH ONE OR MORE SEEDS*

Sampling method	Percentage of area sampled	No. of trips across area	Percentage of estimates within ±5% of actual stocking	Range, in percentage, in accuracy of estimates	
				Min.	Max.
1. Lengthwise† strips of 80 continuous plots	..	..	..	..	..
	2	1	44	21	69
	4	1	40	23	61
4. Strips of 20 continuous plots, parallel and equally spaced	1	1	24	20	80
	2	2	48	22	61
	4	4	52	22	61
5. Strips of 10 continuous plots, parallel and equally spaced	1	1	52	17	70
	2	2	60	32	57
	4	4	44	32	57
6. Strips of 5 continuous plots, parallel and equally spaced	1	1	0	20	57
	2	2	32	20	60
	4	4	44	29	57
13. Every tenth plot on parallel strips	1	5	68	30	57
	2	10	72	34	57
	4	20	88	38	52
15. Four contiguous plots in a square, parallel and equally spaced	1	1	64	27	75
	2	2	64	26	62
	4	4	72	33	55
16. Five contiguous plots in L arrangement, parallel and equally spaced	1	1	28	30	75
	2	2	40	29	57
	4	4	60	34	57
17. Ten contiguous plots in a rectangle (2 × 5 plot arrangement) lengthwise of the area, parallel and equally spaced	1	1	52	20	72
	2	2	64	21	61
	4	4	80	36	52
18. Ten contiguous plots in a rectangle (2 × 5 plot arrangement) crosswise† of the area, parallel and equally spaced	..	..	..	..	..
	2	2	40	27	61
	4	4	36	29	60
19. Twenty contiguous plots in a rectangle (2 × 10 plot arrangement), parallel and equally spaced	1	1	24	17	67
	2	2	40	29	64
	4	4	24	32	62
20. Twenty contiguous plots in a rectangle (4 × 5 plot arrangement), parallel and equally spaced	1	1	48	17	60
	2	2	56	31	59
	4	4	36	29	58

* Actual number of plots stocked was 45 per cent of total number.

† "Lengthwise" is the direction having 80 continuous plots; "crosswise" is the direction having 50 continuous plots. One continuous strip of 80 plots is equivalent to a 2 per cent sample; 2 such strips, in parallel, are equivalent to a 4 per cent sample.

TABLE II (*continued*)

Sampling method	Percentage of area sampled	No. of trips across area	Percentage of estimates within ±5% of actual stocking	Range, in percentage, in accuracy of estimates	
				Min.	Max.
21. Twenty contiguous plots in a rectangle (5 × 4 plot arrangement), parallel and equally spaced	1	1	32	28	62
	2	2	28	39	66
	4	4	20	44	61
23. Series of 10 continuous plots, offset at equal intervals on a diagonal, crosswise of the area	1	1	28	22	65
	2	1	60	31	60
	4	2	64	34	59
24. Series of 5 continuous plots, offset at equal intervals on a diagonal, lengthwise of the area	1	1	44	25	65
	2	1	60	32	55
	4	2	64	36	61

ESTIMATES OF PLOTS STOCKED

Several of the sampling designs were also tested to obtain estimates of the number of plots stocked with one or more seeds. As has previously been stated, this information has been found to be of more general value in forestry than a knowledge of the actual number of seedlings, because tree reproduction often occurs in patches.

The results of the estimates of the percentage of plots containing one or more seeds (see Table II) are quite informative. In the first place, several of the sampling methods appear to be more efficient than others. In the second place, a 2 per cent sample for estimating the percentage of plots stocked seems sufficient. Similar conclusions could not be so clearly drawn from the tests made to estimate the number of seeds.

Series of either 5 or 10 continuous plots offset at equal intervals across the chart yielded, for a 2 per cent sample (*one* trip), estimates of which 60 per cent were within ±5 per cent of the actual percentage of plots stocked. All estimates for these two methods were within ±15 per cent of the actual percentage when 2 per cent of the area was sampled. The practical importance of these results is that by this method only one trip across the chart was required for a fairly reliable estimate of the percentage of stocked plots.

Sampling every tenth plot on parallel strips (method No. 13) for a 1 per cent sample of the area was slightly more reliable for estimating percentage of stocked plots than sampling the diagonally

offset strips, but this method required *five* trips across the chart for the 1 per cent sample.

A 1 per cent sample was generally insufficient for each of the methods tested for estimating the percentage of plots stocked except for method No. 13, which has just been mentioned. Doubling the sample, to 2 per cent, increased the reliability of the estimates for most of the methods considerably. However, taking a 4 per cent sample did not materially add to the reliability of all the estimates. In fact, the reliability of six of the fourteen estimates actually decreased when the sample was increased from 2 to 4 per cent.

Summary and Conclusions

Probably the most important result of this study is that it indicates the possible inaccuracy of estimates of numbers of seedlings in an area obtained from systematic sampling of strips when less than 4 per cent of the area is sampled. At present it is common practice in forestry to count the seedlings on a few milacre quadrats and report the number on a per-acre basis. Our tests reveal that when only 1 per cent of the area is sampled, only one half of the estimates obtained may be within 50 per cent of the actual number. When only 0.5 per cent of the area is sampled, as few as one fifth of the estimates may be within 50 per cent of the actual number. It is clear that in estimating number of seedlings per acre, more than 4 per cent of the area should be sampled. On the other hand, this study shows that a reasonable estimate of the number of plots stocked can be obtained even when less than 4 per cent of the area is sampled.

In forest-reproduction surveys the number of trips necessary across the sample area is an important consideration from the standpoint of cost. For this reason it is common practice to take as many samples as possible on a single strip, and a continuous series of plots or clusters of four or more plots are often used. However, this test indicates that a slightly more reliable estimate can be obtained by offsetting continuous series composed of 5 or 10 plots diagonally across the area to be sampled.

From the numerous sampling methods statistically tested in this study on one rather uniform distribution pattern that was created in the laboratory to simulate a natural population of tree seedlings, the following conclusions may be drawn:

1. Estimates of the total number or quantity of seedlings should be based on samples totaling more than 4 per cent of the area. When the sample is less than 4 per cent, no particular sampling design or sample-plot arrangement can be expected to provide reliable estimates of quantity.

2. Fairly dependable estimates of the percentage of plots stocked with one or more seedlings appear to be possible when as little as 2 per cent of the area is sampled.

3. Offsetting continuous series of 5 or 10 plots diagonally across the sample population may be a sampling method to consider in forest-reproduction surveys.

4. Further distribution patterns should be sampled by the laboratory procedure here described, and the conclusions suggested should be tested in the field.

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SOME RESUPINATE POLYPORES FROM THE REGION OF THE GREAT LAKES. XXV*

DOW V. BAXTER

FORESTERS are especially concerned about fungus populations and about what factors affect the occurrence of the fungi that attack standing timber or wood products. This paper discusses certain wood-rotting species that are found in the region of the Great Lakes, as well as some that are not known there, in the effort to discover what determines both the incidence and the population of these fungi.

Fungus Populations with Reference to Location of Host

The central region of the natural distribution of a host plant is often referred to as the climatic and ecological optimum for the tree. This concept is frequently expressed with reference to the responses of trees to facultative parasites. Although the majority of the resupinate polypores are cosmopolitan, are strictly saprophytic, and are to be found throughout the continent of North America where favorable environments exist, and to a more limited extent where their typical substrata (hardwoods or conifers) occur, the incidence of a few that cause heartrot might at first appear to exhibit some, but not perfect, correlation with the incidence of the host plant

* Throughout the work on these monographs I have been indebted to many individuals and institutions for suggestions, help, and privileges extended to me. Grants from the Horace H. Rackham School of Graduate Studies of the University of Michigan have greatly facilitated both the field and the laboratory studies. My appreciation is expressed particularly to Mr. Richard Zusi and the other men who have accompanied me on my fourteen past expeditions to Alaska, and to those who helped me on the forays to the Yukon Territory, the Cassiar and elsewhere in British Columbia, the Northwest Territories, Newfoundland, and Labrador. Much credit is due them for aiding in the collection and the care of specimens and for living, at times, under rather difficult circumstances. I am under obligation to the scientists of Naturhistoriska Riksmuséet in Stockholm and at the University of Uppsala, Sweden, with whom I have had the pleasure of association. Thanks are also due several American institutions and scholars. To the authorities at the New York Botanical Garden, to the staff of the Division of Pathological and Mycological Collections of the United States Department of Agriculture, and to the Division of Botany, Central Experimental Farms, Ottawa, Canada, I am especially indebted.

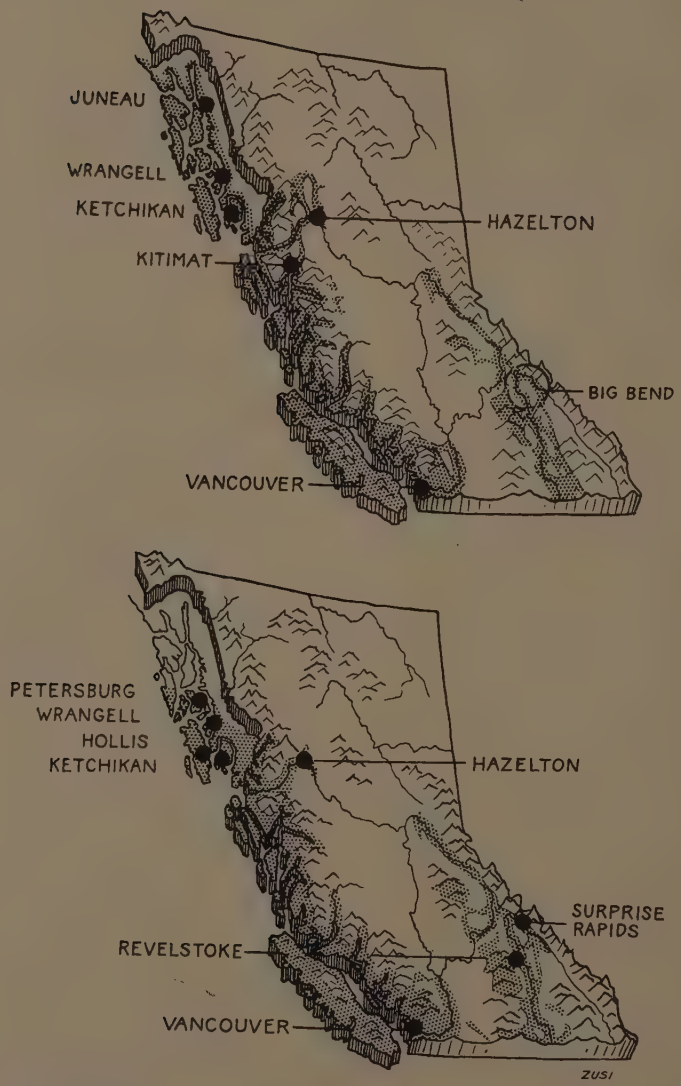

Fig. 1. General distribution in British Columbia of *Tsuga heterophylla* (top) and of *Thuja plicata* (bottom)

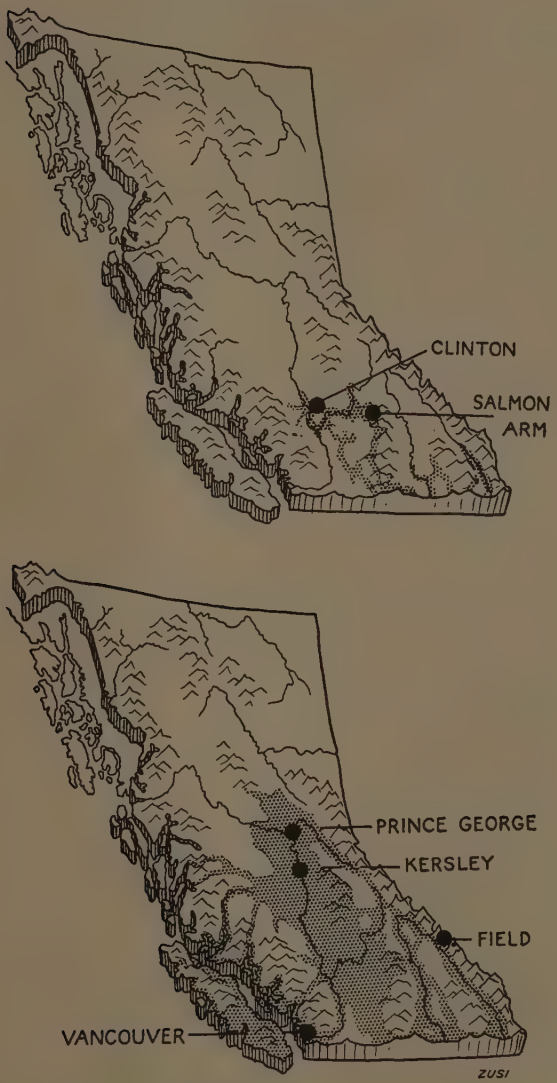

FIG. 2. General distribution in British Columbia of *Pinus ponderosa* (top) and of *Pseudotsuga taxifolia* (bottom)

within its range. *Pora weirii* Murr. and its chief host, *Thuja plicata* (Pl. I), is an example.

The host tree grows in the coastal forests of the southern half of southeast Alaska and southward along the coast ranges of British Columbia, western Washington, Oregon, and northern California. The tree also occurs eastward along many of the interior mountains of British Columbia, northern Washington, Idaho, and Montana. With one exception, the fungus has been collected from all of these areas. It is not known at present from California, and is not, therefore, likely to occur there in sufficient abundance to be economically important.

In British Columbia red cedar grows where Douglas fir does (Figs. 1–2), but thrives best on more moist sites (17). It ranges to the head of Portland Canal (Alaska) and follows the streams inland from the coast. In British Columbia it follows the valley of the Skeena River to a point a short distance beyond Hazelton. Additional observations (to those in coastal British Columbia and Alaska) of the resupinate polypores that attack western cedar were made in the Interior belt, the Shuswap River and the surrounding lake country, the Big Bend country of the Columbia River, and the upper waters of the Fraser River.

Fruiting bodies of *Poria weirii* are more abundant in the forests of the Interior than in coastal cedar, often extending for several feet over fallen logs (Pl. II) and commonly observed at the bases of fire-scarred stumps and trees. The fungus does occur, however, in coastal regions. In paper XXIV of this series (1) *P. weirii* is reported on timber products at the Old Kaasan Indian village, Prince Edward Island, Alaska. In general, my observations on fruiting-body occurrence, made over large areas, confirm previous observations by other investigators (see Table I, derived from Buckland [5]) on the incidence of *P. weirii*.

In forests near the northeastern limits of the range of Interior western red cedar in British Columbia (Fig. 1) the cull in cedar is high. The quantity of fruiting bodies (not necessarily a criterion for the volume of decay) of *Poria weirii* that may be collected here within any given time would exceed that in most localities farther west on the coast and in other sections of the country nearer the center of the host range. For cedar grown in the Interior areas and varying in age from fifty to two hundred and fifty years, Buckland (5) reports thirty-two isolations of *P. weirii* for one from coastal cedar. But if western red cedar is considered with reference to

P. albipellucida Baxter (described in paper IX of this series [1]), which also causes a significant rot in this tree, it becomes evident that factors other than mere distribution within the range of the host are operating.

Fungus Populations with Reference to Moisture and Humidity

Poria albipellucida was collected originally on coastal British Columbian western red cedar. I have never found this fungus in Interior forests in either the United States or British Columbia, in spite of numerous searches. Moreover, Buckland (5) obtained only one culture of it from Interior-grown cedar, but isolated sixty-three

TABLE I

Infection in Interior and Coastal Belts by the Principal Wood-destroying Fungi*

Wood-decaying fungus	Interior poles		Coast poles		Coast sawlogs		Total	
	Entire no. of infections	No. of mixed infections	Entire no. of infections	No. of mixed infections	Entire no. of infections	No. of mixed infections	Total no. of infections	Total no. of mixed infections
Poria weirii	40	27	0	0	2	0	42	27
Poria albipellucida	1	0	63	21	126	35	190	56

* One hundred and ten cedar poles and logs were examined in the Interior and 615 on the coast (Buckland's 1946 report [5]).

cultures from coastal-grown cedar that was within the same age groups reported for such cedar as a host for *P. weirii*.

Moisture and, especially, the amount of humidity are believed to be the major factors involved. Later, during different years and during relatively drier periods than existed on the coast when *Poria albipellucida* was discovered, fruiting bodies of this fungus were not found at all, even within the type locality, though they were common at the time the original collections were made. The usually somewhat drier environment in the Interior areas does not prohibit the continued life of the fructification of *P. weirii* on Interior cedar, but fructification of *P. albipellucida* is greatly restricted. That *P. albipellucida* is important as a destructive agent of *Thuja plicata* only

on the coast might be explained by the dependence of the species upon high relative humidity for its fructification. The effects of moisture upon fructification of *P. weirii* in coastal cedar are not so clear, but the corky nature of the fruiting body does favor its remaining as a potential source of inoculum over longer periods in the somewhat drier atmosphere of the Interior cedar sites. Experiments on the sporulation of the two fungi should be made.

Fungus Populations with Reference to Local Conditions

As concerns the incidence of polypores that do not cause heartrots of green standing trees but produce rot in fallen timbers, abundance is more readily correlated with catastrophes (such as windfall, fire, or insect damage) and local conditions (2). These conditions may or may not be as favorable for fructification at the fringes of tree distribution as in areas closer to the center of the tree's range. Except for *Poria weirii*, the same porias that attack coniferous woods—western hemlock, Douglas fir, and ponderosa pine, for example—at the borders of their appearance in North America (Figs. 1–2) occur in the Lake States.

Collections made at the limits of growth of the coastal coniferous forest of the continent, that is, on Sitka spruce on Kodiak Island, indicate that rot in relatively young trees is common. Much of this is due to the open-grown stands and the consequent extreme branchiness of the trees, which resulted in relatively young trees becoming infected with heart-rotting fungi. A greater volume of rot, however, is to be observed in the larger and overmature Sitka spruce farther south in Alaskan coastal forests.

Fungus Populations with Reference to Temperature

Polyporus leucospongia is not known to occur in the Lake States. This is not because of a lack of coniferous timbers, but because of the relatively warm summer temperatures.

This fungus is perhaps the most important economically of all the wood-destroying fungi that attack wood in service at high elevations. Untreated bridge timbers and highway guard railings are readily decayed by it, especially at elevations above seven thousand feet. Untreated timbers are used extensively in highway construction in western and northwestern national parks (Pl. III). Because of relatively cold temperatures at night even during the summer, such a fungus as the ubiquitous *Lenzites saepiaria* Fr. that attacks

wood in service in most out-of-door environments grows so slowly that railings are decayed chiefly by the faster-growing *Polyporus leucospongia*. Laboratory tests readily demonstrate that *Pol. leucospongia* grows best at temperatures of only 7° to 10° C. (Pl. IV).

Fungus Populations with Reference to Barriers

Both land and water barriers are less effective in limiting the distribution of fungi than in limiting that of flowering plants (13). For North America, no large areas illustrate the effect of barriers upon the distribution of the wood-destroying fungi more clearly than do those in the Pacific Northwest.

Although it is the pattern for the amount of cull caused directly by heart-rotting organisms to vary with the age of the timber, and often with local sites, range studies of some fungi point to either their absence or their scarcity under general conditions that favor their occurrence in near-by locations. Among wood-destroying fungi, variation in the occurrence of *Fomes pini* and *Echinodontium tinctorium* (Indian paint fungus)[1] is of interest.

My collections of Alaskan fungi made during a period of fourteen field seasons indicate that all specimens of *Echinodontium tinctorium* are from mainland areas in the Tongass and Chugach national forests—Skagway, Hope, and Moose Pass, for example. Numerous efforts to collect this fungus on such large Alaskan islands as Admiralty, Prince of Wales, Chicagoff, Baranoff, Kodiak (western hemlock is not present as a possible host conifer on Kodiak) and on many smaller islands have been fruitless. *Fomes pini*, on the other hand, is often abundant. Even the population of *F. pini*, however, varies greatly, so that in many wide areas of overmature Alaskan Sitka spruce forests, the incidence of the fungus seems to depend more upon locality than upon the age of the timber.

These records for Alaskan fungi correspond to the pattern suggested for British Columbia by Foster and Foster (9) and by Foster and Ziller (10). The Indian paint fungus, long known as the most serious fungus associated with western hemlock on the mainland and throughout most, if not all, of the range of this tree in the interior of the province, is not known to occur on the Queen Charlotte Islands. The water barrier, and not inadequate sampling, appears to be the explanation of differences in occurrence between mainland and island

[1] This fungus is an economically important cause of heartrot in western hemlock and the true firs, but it is not classified as a polypore.

regions, as has been pointed out for British Columbia (9), as well as for Alaska. The presence of barriers probably explains, at least in part, differences in both the amount of decay and the causes of the rot reported for western hemlock by various investigators.

Specific Descriptions

Polyporus cuneatus (Murr.) Zeller, Mycologia, 21: 101. 1929

Description.—(See paper XII of this series [1]).

Recognition.—There are few polypores on western red cedar that may be classified under the genera Polyporus or "Polystictus." The flexible or pliable nature of the fruiting bodies of *Polyporus cuneatus* when old may suggest weathered *Polyporus abietinus*, but the color of even the old pores as well as that of the surface of the pileus of *Polyporus cuneatus* remains whitish or cream. The mouths and the surface of the pileus are often concolorous in *Polyporus cuneatus*, but in *Polyporus abietinus* the pores in age may change from a pink or violet shade to brownish, and generally they are not concolorous with the surface of the pileus.

Polyporus cuneatus often grows out through the bark to form a resupinate plant that readily suggests a poria. In this state, collections may sometimes resemble specimens of *Poria asiatica* (Pilát) Overh., which is known on western red cedar. *Pol. cuneatus*, however, covers more of the log than does *P. asiatica*. The spores of *P. asiatica*, moreover, are oblong or short-cylindric, 3–4 × 1.5–2 μ, and cystidia are abundant. In *Pol. cuneatus* the spores are globose, 3–4 μ.

Habitat.—*Abies lasiocarpa*, *Libocedrus decurrens*, *Sequoia sempervirens*, *Thuja plicata*.

Distribution.—Alaska, British Columbia; California, Colorado, Idaho, Montana, Oregon, Washington.

Occurrence.—*Polyporus cuneatus* occurs on both coastal and Interior western red cedar. It is most frequently seen inhabiting densely shaded logs, and is common on rustic timber structures where the bark has not been removed.

Decay.—*Polyporus cuneatus* causes a white spongy rot of the sapwood.

Importance.—*Polyporus cuneatus* is the single organism most responsible for decay of cedar sapwood and slash. Approximately five years after the extensive blowdown of northwest timbers in the Olympic Peninsula, in Washington, for example, fruiting

bodies of *Pol. cuneatus* appeared on 22.4 per cent of the western red cedar sampled, and caused most of the identified rot in that species (4). It is reported that 13 per cent of the total decay, board-foot measure (or 14.4 per cent, cubic-foot measure), in the western red cedar in a windfall estimated at 3.5 to 9.5 billion feet, board-foot measure, of western red cedar, Douglas fir, Sitka spruce, silver fir, and western hemlock was due to this fungus. It was not active in any other species.

Polyporus leucospongia Cooke & Harkn., Grevillea, 11: 106. 1883

Spongiporus leucospongia (Cooke & Harkn.) Murr., Bull. Torr. Bot. Club, 32: 474. 1905.

Fructification laterally elongate, effused-reflexed, or on under side of log resupinate with reflexed part on all sides, spongy; surface tomentose, cottony, shading from cream color to "light buff"[2] throughout and varying to half or more than half the thickness of the pileus; margin inflexed, often extending over mouths at borders; context duplex, interior layer white and soft, spongy but not nearly so elastic as outer layer; tubes at first whitish, their mouths soon stained tawny, cinereous or "ochraceous buff," then "ferruginous"; tubes up to 1 cm. long, entering the context and pileus unevenly; mouths 2–3 to a mm.; dissepiments entire or toothed, thin, at length lacerate, fringed; basidia 4-spored, 25–27 × 3.5–4 μ; spores cylindric or allantoid, smooth, hyaline, 5–8 × 1–1.5 μ; hyphal pegs present, composed of 2–3 or more hyphae arranged in parallel or interwoven, projecting 25–35 μ above the level of the hymenium (Shope [16]); no cystidia.

Recognition.—*Polyporus leucospongia* is easily recognized in the field by the spongy nature of the fruiting bodies. There are no related species that might be readily confused with this fungus.

Habitat.—*Abies concolor, A. lasiocarpa, A. magnifica shastensis, Arctostaphylos patula* (6), *Larix lyallii, L. occidentalis, Libocedrus decurrens, Picea engelmannii, Pinus albicaulis, P. contorta latifolia, P. flexilis, P. ponderosa, Pseudotsuga taxifolia, Tsuga mertensiana.*

Distribution.—Alaska, British Columbia; California, Colorado, Idaho, Montana, Oregon, Utah (11, 15), Washington, Wyoming.

[2] Color terms within quotation marks are those of R. Ridgway, *Color Standards and Color Nomenclature* (Washington, D.C., 1912).

Occurrence.—*Polyporus leucospongia* grows commonly on decorticated coniferous wood, and especially on Engelmann spruce and lodgepole pine. The fungus, therefore, is found chiefly in the montane and subalpine zones, and then mainly in the Rocky Mountain and the western Coast Ranges. The lower altitudinal limit appears to be about 7,000 feet, on Mount Shasta, in California (6). *Pol. leucospongia* is not, however, a fungus of the northern forests of North America. Although in this series of papers it is reported from Alaska, it is extremely rare there. No records are known of its occurrence in the Yukon Territory.

Cultures.—*Polyporus leucospongia* is one of the most unusual polypores known, with reference to its temperature requirements. Unlike most wood-destroying fungi, it does not make satisfactory growth at ordinary room temperatures, but develops best at approximately 7°–10° C.

Decay.—*Polyporus leucospongia* causes heartrot and saprot of decorticated timber. The affected wood becomes somewhat yellowish and eventually breaks up into more or less cubical masses.

Importance.—This fungus is an important cause of decay in decorticated and relatively large slash in windfalls and fire-killed timber in the montane zones of the Rocky Mountain and West Coast forests. Its destruction of such slash may be a significant factor in fire prevention for certain areas.

Polyporus leucospongia is often the chief cause of decay in round timbers placed in service at relatively high elevations. For example, the fungus attacks highway guard railings and makes costly replacements necessary in various places in Yellowstone Park. It attacks posts and trail markers in service; the fungus has been observed on such timbers on Mount Shasta, growing considerably above the highest tree zone (6).

Polyporus fibrillosus Karst., Sydv. Finl. Polyp., p. 30. 1859

Polyporus aurantiacus Peck, Ann. Rep. N. Y. State Mus., 26: 69. 1874.
Inonotus fibrillosus Karst., Bidr. Finl. Nat. Folk, 37: 72. 1882.
Polyporus shiraianus P. Henn., Bot. Jahrb., 28: 269. 1900.
Pycnoporellus fibrillosus (Karst.) Murr., Bull. Torr. Bot. Club, 32: 489. 1905.

Fructification soft and spongy or somewhat watery when fresh, 3–6 × 4–10 × 0.5–2 cm. (Shope [16]), fragile upon drying and

readily attacked by insects, sessile, dimidiate, imbricate, or somewhat effused-reflexed (depending upon the nature of the substratum) and occasionally almost entirely resupinate; surface fibrillose, zonate, "light salmon orange" to "zinc orange" or "capucine orange"; context spongy when dry and sodden when wet, concolorous with the surface of the pileus, 0.5–1.5 cm. thick; tubes 2–6 mm. long; mouths "antimony yellow" or "light salmon orange" to "zinc orange" or "tawny" in age; dissepiments becoming lacerate; basidia 4-spored; spores hyaline, smooth, elongate-ellipsoid, 5–9 × 2.5–4 μ; hairlike cystidia conspicuous, hyaline, cylindric, 3–4 μ in diameter and projecting up to 60 μ.

Recognition.—Because of its colors, *Polyporus fibrillosus* may suggest *Pol. cinnabarinus* (Jacq.) Fr. *Pol. cinnabarinus* occurs rarely on coniferous trees, whereas *Pol. fibrillosus* is seldom found on broadleaf species. The spores of both species are short-cylindric, but there are no cystidia in *Pol. cinnabarinus.*

Colors may also be similar in *Polyporus alboluteus* and *Pol. fibrillosus. Pol. alboluteus* may be distinguished by the fact that it is mostly resupinate, and the mouths are large, i.e., 1–3 mm. broad. In *Pol. fibrillosus* the mouths are smaller, being 1–2 to a mm. The tubes of *Pol. alboluteus* may become as much as 3 cm. long, whereas those of *Pol. fibrillosus* are never so long as 1 cm., and they are mostly 2–6 mm. long.

Habitat.—*Abies balsamea, A. grandis, Betula papyrifera, Larix occidentalis, Picea engelmannii, P. mariana, P. rubra, P. sitchensis, Pinus monticola, P. ponderosa, P. resinosa, Pseudotsuga taxifolia, Thuja occidentalis, Tsuga canadensis, T. heterophylla, T. mertensiana.*

Distribution.—Alaska, British Columbia, Ontario; Idaho, Louisiana, Minnesota, Montana, New Hampshire, New York, North Carolina, South Dakota, Tennessee, Washington, West Virginia.

Occurrence.—This fungus is widely distributed (Pl. V), but never abundant, in the forests in any region of the United States. It is more common in the Pacific Northwest than elsewhere. Although it is found chiefly on conifers, it occasionally attacks broad-leaved species.

Cultures.—This fungus may be readily distinguished in culture since its growth patterns differ from those of other wood-destroying polypores. Growth of *Polyporus fibrillosus* is moderately rapid.

The mat is white, with the growth at first submerged but later developing into more or less extensive areas of appressed to slightly raised floccose to cottony mycelium, which forms a fruiting surface (12).

The hyphae in the advancing zone are hyaline and up to 4.5 μ in diameter; hyphae with a greenish-yellow color are apparently aseptate, branched, 4.5–6 μ in diameter. Basidia are 4-spored, with spores 4.5–6.0 $\times$ 3.0 μ. Cystidia are numerous and thin-walled, 3–4.5 μ in diameter (12).

Polyporus fibrillosus does not produce a diffusion zone on gallic or tannic acid media (7).

Decay.—*Polyporus fibrillosus* causes a brown trunk rot in living Sitka spruce (3). The fungus produces decay in both the heartwood and the sapwood of windthrown timber, but such a small percentage of the down timber is attacked that no economic significance can be attributed to its occurrence.

Poria luteoalba (Karst.) Sacc., Syll. Fung. VI. p. 299. 1888 (sensu Eriksson, Svensk Bot. Tidskrift, Bd. 43, Heft 1. 1949)

Important specimens:

Physisporus luteoalbus Karst. on pine, Sept. 1886. Coll. P. A. Karsten, Herb. P. A. Karsten, Helsingfors, Finland. (This plant is not regarded as *P. luteoalbus* in the strict sense of *luteoalbus* in the present manuscript.)

Physisporus luteoalbus Karst. on pine, Mustiala, Oct. 13, 1886. Herb. P. A. Karsten, Helsingfors, Finland.

Physisporus luteoalbus Karst., Mustiala, May 1887. Coll. P. A. Karsten, Herb. P. A. Karsten, Helsingfors, Finland.

Physisporus luteoalbus Karst., Nov. 1886, Sept. 7, 1892. Herb. P. A. Karsten, Helsingfors, Finland. (Collection is obviously mixed up.)

Fructification thin, resupinate, effused usually in elongated patches for about 6 inches, whitish but soon becoming yellow-brown; margin white or "tilleul buff" and lighter than the pore surface; pores 0.2 mm. in diameter, regular; subiculum distinct; basidia clavate, 12–15 $\times$ 3–5 μ; spores cylindrical, straight or somewhat curved, hyaline, smooth, 4–5 $\times$ 1.5 μ (8); tramal hyphae thick-walled, 2–5 μ wide, hymenial hyphae thin-walled; encrusted cystidia present.

Recognition.—Although existing specimens collected by early workers may be interpreted variously for the *Poria vulgaris* complex, it is best to recognize the views presented by Eriksson (8). In the

P. vulgaris group he records seven types, six of which have specific rank. *P. luteoalba* (Karst.) Sacc. is one of them (Pl. VI).

Poria luteoalba ordinarily dries darker, i.e., "cream buff," "ochraceous tawny," "tawny," "cinnamon," or "clay color," than the true *P. vulgaris*. The fruiting body is thin (1–2 mm. thick). Its firm consistency is also a distinctive feature. It might suggest a thin specimen of *P. subincarnata*, which is also placed in the *P. vulgaris* group. *P. luteoalba* differs microscopically from all other species in the *P. vulgaris* complex (*P. subincarnata* (Pk.) Murr., *P. byssina* (Pers.) Rom., *P. lenis* (Karst.) Sacc., *P. xantha* (Fr.) Cooke, *P. crassa* (Karst.) Sacc.) in having cystidia. Conspicuously encrusted hyphae are present, however, in *P. subincarnata* (spores 4.5–6 × 1 μ) and encrusted "paraphyses or cystidioles" (8).

Poria rixosa is also "pale pinkish buff" and firm, and has encrusted cystidia. In general, this plant is somewhat coarser, thicker, and more widely effused than *P. luteoalba*, but there is no doubt that the two plants may be confused in certain stages of development. Mature specimens of *P. rixosa* may sometimes be two-layered. Overholts (14) reports few or no clamp connections in *P. rixosa*. Clamps are present in *P. luteoalba*. Color differences and thickness of growth in most collections will serve as a means of distinguishing the two plants. They have not been compared in culture.

The colors of *Poria eupora*, also a thin plant, might lead to misinterpretation of some collections. *P. luteoalba* in all probability should be placed near *P. eupora* with reference to relationship. The spores of *P. eupora*, however, are ellipsoidal, 3–4.5 × 2–3 μ, and not cylindrical, 4–5 × 1.5 μ. *P. luteoalba* is found on conifers. *P. eupora* grows on both conifers and hardwoods, but is found mostly on hardwoods.

Habitat.—*Abies balsamea*, *Larix occidentalis*, *Picea sp.*, *Pinus divaricata*, *P. contorta latifolia*, *P. radiata*, *P. strobus*, *P. virginiana*, *Tsuga heterophylla*.

Distribution.—Northwest Territories, British Columbia, Quebec; California, Delaware, Florida, Maine, Massachusetts, Mississippi, New Hampshire, Wyoming.

Occurrence.—The species occurs much more widely in North America than existing records of distribution indicate.

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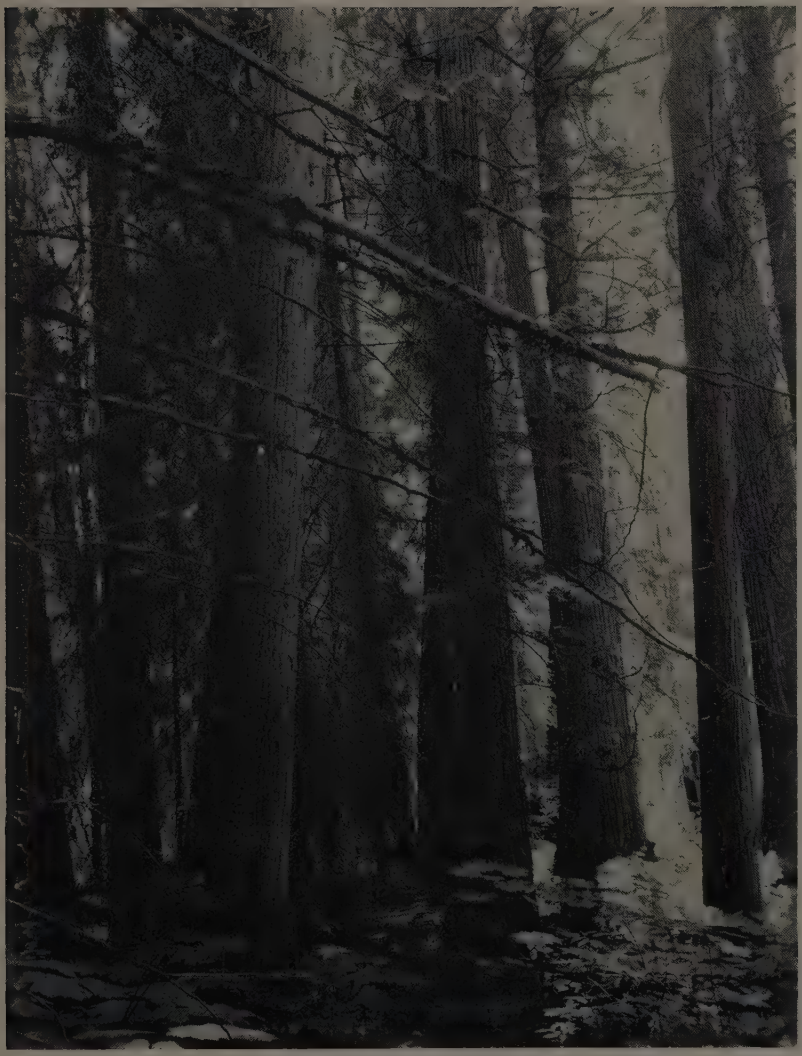


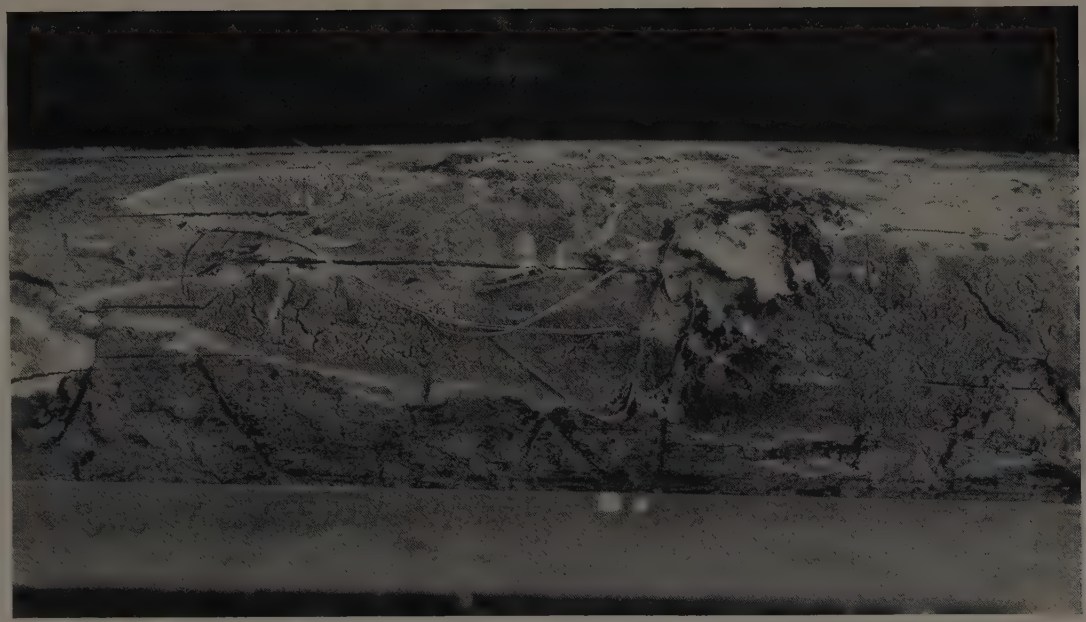
Interior western-red-cedar forest, Surprise Rapids, British Columbia

Interior-grown western-red-cedar log with *Poria weirii* Murr.

Polyporus leucospongia on highway timbers, Yellowstone National Park, Wyoming

Polyporus leucospongia from Cline Top Mesa, New Castle, Colorado: lower left, grown for one month at 10° C.; center top, grown for two weeks at 10° C.; lower right, grown for two weeks at 25° C. Culture 97414, U. S. Div. Forest Pathology

Resupinate *Polyporus fibrillosus* on *Tsuga heterophylla*, Maybeso Creek, Hollis, Alaska



Poria luteoalba (Karst.) Sacc. sensu Eriksson on *Pinus divaricata*, Fort Smith, Northwest Territories

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THE ACCURACY OF OCULAR ESTIMATES OF FORM CLASS IN STANDING TREES

JOHN CAROW

IN RECENT years the Girard form class has seemed to provide a new and improved solution to the old problem of measuring merchantable volume in standing trees. At the moment this measure of form in sawlog trees has enthusiastic support all over the country, but it also has its critics—foresters who question whether it is of lasting and fundamental importance or whether its current popularity will not wane with the years and with the accumulation of unspectacular results. My own experience with it in attempting to teach students at Camp Filibert Roth, Iron River, Michigan, how to estimate merchantable volume may be of some value in this connection.

As is well known, the Girard form class for any tree is the ratio of the scaling diameter of the first 16-foot log to the d.b.h. of the tree. It has been found that the form class of the great majority of trees falls in a relatively narrow range, between .75 and .85, with .78 being the average for most species. Once the form class has been decided upon, this figure times the d.b.h. gives the scaling diameter of the butt log, and does so with a precision that is usually higher than that achieved when the scaling diameter is estimated directly. When the butt-log size has been determined, the other log sizes can be found from taper estimates or by use of the average-taper tables.

With form class taken as a third independent variable, along with d.b.h. and height, sets of volume tables have been prepared and satisfactorily employed for cruising various species in many sections of the country. The Mesavage–Girard (2) tables that were published by the United States Forest Service at the end of the war (1946) have had wide use in the eastern and southern states, and the tables prepared by Girard and Bruce (1) for Douglas fir and western pine are now applied over much of the West. These compact books appeal greatly to foresters who have labored through years of cruising aided only by a miscellaneous array of species tables of local application. The one drawback is that the measure-

ment of the third variable, form class, takes time and costs money. Is it worth the price? The backers of form-class tables point to cruises where their use has given phenomenal results. They contend that, with a little training, a good cruiser can learn to estimate form class ocularly with acceptable and consistent results. He comes to recognize a tree of average form and then judges the others by plus or minus deviations from the average. Some cruisers estimate the form of every cruised tree. Others estimate a local average for each species, for species and height classes, or for species and diameter groups. Still others just use the form-class .78 table for all trees.

The claims and arguments of users of form-class tables have not convinced all foresters. There is still much skepticism. Investigators have found that sometimes form class seems to be correlated with d.b.h., whereas in other locations it seems to be correlated with height. Species differences certainly affect form class, but within a species individual trees may vary widely. Spurr (4) recognized that form-class tables give results that are superior to those from conventional tables, but only when form class is accurately measured for each tree. He does not favor the general use of form-class tables because he fears that with careless and inaccurate application they will actually give poorer results than conventional ones. Schnur (3) also found that form-class volume tables gave good results, but he cautioned that ocular estimates of form class were likely to result in considerable error.

The key question regarding the application of form-class volume tables appears to lie in the ability of the user to determine form class. If form can be reliably determined by ocular estimation, then the method is a sound one. However, if ocular estimates cannot be relied upon, and actual measurement must be made, the cost of arriving at this third variable may offset any gain in accuracy and in tabular convenience.

I have had considerable experience with form class. My first training was received from Girard himself, in 1940. I have been using the method and teaching others to use it ever since. The best way to teach form-class estimation, I believe, is to have the students measure form class in standing trees. Careful consideration is first given to the overall appearance of the bole and to possible abnormal thickness of the bark. Then the tree is climbed, and the actual scaling diameter and form class are determined. As the men progress

from tree to tree, they become acquainted with the appearance of the average tree and with normal deviations from it. Soon the trainee should be able to tell whether the form class of a tree is higher or lower than the average. Provided he can be consistent in estimating the direction of deviation, his final volume estimates should be better than if the average were used without variation.

In my teaching of the use of form class at Camp Filibert Roth, I had been encouraged because the butt-log volume estimates of two thirds of the students had come within 3 per cent of the figure obtained from measuring scaling diameter. This means that though the form classes of few of the sample trees may have been estimated exactly, the average estimate did not differ from the average measurement by more than one form-class percentage.

Recently, however, I had occasion to spend a few days going over the records made by students in the form-class estimation exercises and to subject them to a statistical analysis. The results have not supported my initial optimism.

A group of twenty-two students last year estimated butt-log volumes for 25 test trees and averaged only 1.1 per cent below the actual scale. This sounds good until it is compared with the .5 per cent error that would have resulted if no estimation of form class had been made at all and the average form class of .79 had been used instead for every tree. Individual students ranged in error from .1 to 5.7 per cent. As had been expected, only a few estimates were precise, but if a large proportion of the above- and below-average trees had been properly identified as high and low, then good correlation of estimated to actual form class would have resulted. This did not happen, however. The analysis showed that though they were less than one form-class percentage low on the average, these beginners were inconsistent in their tree-by-tree judgment.

For a closer look, I selected the papers of three good students and calculated the correlation coefficient between estimated and measured form class for the 25 trees in the sample. The average value for the three was .24, which indicates that only 5.5 per cent of the variation in measured form class was recognized by the estimates.

The low correlation between estimated and actual form class as revealed by the data from my students set me to investigating my own efficiency. Perhaps the reason for the poor showing was lack of experience. How much better could the instructor do?

For the same 25 trees the correlation coefficient between my estimates and the measured values was .46. While it was some consolation to know that I had done better than my pupils, I could take no great pride in being able to account for only 22 per cent of the measured variation. How well could the late Mr. Girard have done? I know of no similar test of his estimating ability, and though he had an uncanny eye for form and size, I doubt if even his estimates would have had a high precision in statistical terms.

The conclusion I have been forced to accept is that ocular estimates of form class are not so good as I had thought they were. Even with some training, it is doubtful that the average forester can do better work by making ocular estimates of individual tree form than he could by using a single average form class for all the trees of a species or for size groups within a species. If the average form class is estimated, the cruiser should realize that with normally tapering trees an error amounting to a difference of one form-class percentage means an error amounting to 3 per cent in board-foot volume. It would be better to get the average from a measured sample taken in the area being cruised. My data from the fairly uniform northern hardwoods around Camp Filibert Roth indicate that a sample of 10 trees will give the average form class within an error of one form-class percentage, with a probability of 2 to 1. Forty sample trees would be required to give the average form class within the same degree of error at a 95 per cent level of probability. If sample measurements are too costly or too troublesome, then the cruiser who wants high accuracy will be well advised to go back to the use of conventional volume tables of proved value.

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COMPARATIVE VALUATION IN FOREST MANAGEMENT

KENNETH P. DAVIS

IT USED to be true that almost anything positive done in American forestry was good, and that more of it would be better. When no control over cutting methods is being exercised, positive steps to provide for regeneration, improve stand quality, and the like are clearly desirable—scant analysis is required to substantiate the point. Where there is no forest-fire control, some is obviously needed, and a little fire control may patently still be inadequate.

But while there is much yet to be done that clearly needs doing, the time is coming, and has already arrived in many instances, when the words "obviously," "clearly desirable," "self-evident," and the like are not sufficient evaluations. We cannot fall back on the stock answer that more of everything is needed. Forest-fire control has been brought in some states, or in parts of some states, to a level that makes appropriate a careful comparison of costs with expected benefits. Development of large-scale commercial timber growing by private and public agencies has made questions of returns in relation to costs both frequent and pressing.

Factual information about our forests, increasingly being accumulated from silvicultural research and experience, indicates the physical results that may be expected from specific forest operations. Financial or, more broadly, economic considerations determine what is possible in a particular situation in so far as measurable economic gain is a controlling objective. I do not argue for a minute that everything done in forestry can or should be judged solely on the basis of direct economic profit, or that all values known to exist can be measured in monetary terms. But many questions and problems hinge directly on financial considerations, and, to the extent that they do, it is maintained that the reaching of sound decisions is greatly aided by using the best valuation procedures available.

Valuation of financial alternatives, or comparative valuation, as it is sometimes called, is an analytical comparison of costs with returns

in order to arrive at a judgment of value, usually measured as of the present. While the best factual data available should by all means be used and the results made as significant as possible in absolute terms, a deeper purpose of such valuations is to obtain answers truly comparable and accurate in relative terms. That is, a major aim is to bring out the relative financial merits of one possible line of action as compared with another. Whether one or another course is desirable as a business proposition depends on practicable alternatives.

Two basic kinds of information are essential to any valuation analysis. They are: (1) data on costs, which must be defined both as to amount and as to time of payment, and (2) data on returns, or benefits stemming from the costs, which must be defined both as to amount and as to time of receipt. Whenever there is a substantial interval between investment and return—as is common in forestry undertakings—consideration of a third element, interest, is necessary to measure the financial importance of the passage of time.

The need for information on costs and resultant returns in forestry undertakings is accepted, at least in principle, by almost everyone, although determination of these items is often difficult and may require the asking of some annoyingly specific questions. The valuation process necessitates being very specific concerning such matters. The inclusion of the third element, the interest factor, is much less generally accepted and understood; many people have inhibitions about employing interest. Without going into the whys and wherefores of interest and its computation, it may be said that in financial matters consideration of interest is as inescapable as consideration of time. To argue against the inclusion of interest, necessarily compounded if its payment is deferred, is the same as arguing that time is of no financial importance, that a dollar due ten years hence is worth as much as a dollar in hand now, that the use of capital in enterprise is not worth anything. Certainly no businessman can afford to take such a view—the degree to which the public can is a debatable matter.

With this general background regarding the nature and the place of comparative valuation in mind, I should like to illustrate its application in two practical problems. Forest pruning will serve as an excellent and familiar example. A good deal of research has been carried on to obtain factual information on methods of pruning, costs, rate of occlusion, effect of crown removal on growth, pathological consequences, and the like. The amount and the time of

returns and the fact that the desirability of pruning must be measured almost entirely in monetary terms have received much less recognition and attention. The valuation problem in this instance is, basically, to balance the cost of removing a certain portion of the lower crown, in one or more pruning operations, against the resultant increased value of the tree to be realized at some future time.

As an illustration, data on pruning white pine in Saginaw Forest, near Ann Arbor, Michigan, are given, for two trees, in Table I. The exact figures are not especially important—it is the pattern of the problem that is to be emphasized here. These few data call attention to the essential parts of the valuation problem. Costs are

TABLE I

Costs and Estimated Returns in Pruning Two White-Pine Trees

Item	Tree No. 1 (a dominant)	Tree No. 2 (a codominant)
Present d.i.b.*	5 inches	5 inches
Estimated d.i.b. after pruning scars have healed over	6 inches	6 inches
Estimated d.i.b. after 40 years	10.6 inches	9.4 inches
Cost of pruning	$0.30	$0.30
Estimated increase in value after 40 years due to pruning	$2.66	$1.40
Ratio of costs to returns	8.87	4.67
Rate of return on cost	5.6%	3.9%

* The d.i.b. is the diameter measured inside the bark at the top of the first 16-ft. log.

what they are; they can usually be determined with reasonable accuracy, although much research and experience may be required to discover the best procedure in relation to cost in a particular situation. The estimated increase in value due to pruning is based here on a forecast of tree growth and of the probable lumber value of the logs with and without a rim of knot-free wood outside the knotty core. The trees' expected value in veneer or some other product might well have been appraised instead, for there are a number of possible benefits from pruning to be considered.

That product values forty years hence are uncertain is perfectly true, but if pruning is to be undertaken at all it must be done on the assumption that some increase in value will result. Setting a figure for this increase is one of those annoyingly specific questions men-

tioned earlier. The relation of rate of growth to rate of return may be seen by comparing the data for the two trees. General quality remaining about the same, the faster a tree grows the greater is the return, not only as to increase in total value of the tree, but as to increase in value specifically due to pruning.

By frankly recognizing that pruning is a value-augmenting process, attention is focused on the importance of estimating both cost and return. Where pruning is warranted at all, there is little justification for not employing available man-hours or dollars to obtain the maximum net return possible. Recognition of pruning as a problem in economic valuation gives point to research by orienting it toward the factual determination of how and where pruning can be most efficiently applied.

The approach here illustrated may be used to evaluate the desirability, at least in relative terms, of almost any stand-improvement operation, such as a cleaning, the disposal of unmerchantable hardwoods, or a thinning. The basic valuation pattern is the same, and the analysis of various methods and their costs in relation to prospective returns would again serve to guide research.

Another general application of valuation analysis is in appraising one possible land use as compared with another. To illustrate, suppose that it is desired to investigate the growing of Christmas trees on a particular tract of land in southern Michigan. Let us assume that one course might be to rent land and grow Scotch pine under intensive culture for quality production, in the following circumstances:

1. That 1,500 two-year-old trees are planted per acre.
2. That 20 per cent, or 300, die during the first year and are replanted during the second year.
3. That 85 per cent of the original number, or 1,275 trees, attain harvest age of 8 years. Of these, 60 per cent make first-quality trees, 20 per cent are of medium quality, and 20 per cent cannot be sold.
4. That the plantation is sprayed annually to control insects and that, beginning with the third year, annual trimming and shaping is done to improve quality.

The net income over costs from such a plantation, reckoned on the basis of reasonable cost and return figures, and with interest assumed to be at a commercial rate of 6 per cent, is estimated in

TABLE II

COSTS AND ESTIMATED RETURNS IN GROWING SCOTCH-PINE CHRISTMAS TREES IN SOUTHERN MICHIGAN

Income or cost item	Value per acre	Formula for value accumulation with interest	Value of interest factor	Total value or total cost at harvest age
Income items				
Stumpage value of first-quality trees (60% of 1,275 at $1.75 per tree)	$1,338.75	.....	.....	$1,338.75
Value of medium-quality trees (20% of 1,275 at $0.85)	216.75	.....	.....	216.75
Total income	.....	.....	.....	$1,555.50
Cost items				
Planting stock (1,500 trees at $35.00 per M)	$52.50	$(1.06)^8$	1.5938	$ 83.67
Planting 1,500 trees	22.50	$(1.06)^8$	1.5938	35.86
Replanting 300 trees including stock	18.00	$(1.06)^7$	1.5036	27.06
Shaping 80% of 1,275 trees at 5¢ per tree:				
At age 3	51.00	$(1.06)^5$	1.3382	68.25
At age 4	51.00	$(1.06)^4$	1.2625	64.39
At age 5	51.00	$(1.06)^3$	1.1910	60.74
At age 6	51.00	$(1.06)^2$	1.1236	57.30
At age 7	51.00	$(1.06)^1$	1.0600	54.06
Clearing land for replanting	.....	.....	.....	8.00
Annual spraying	15.00	$\frac{(1.06)^8-1}{0.06}$	9.8975	148.46
Annual land rental	3.00	$\frac{(1.06)^8-1}{0.06}$	9.8975	29.69
Total costs	.....	.....	.....	$637.48
Net income at harvest age				$918.02
Present net worth—$918.02 ÷ $(1.06)^8$				575.99

Table II. The present net value shown there, $576 an acre, is frankly an estimate, and no better or worse than the assumptions behind it. This amount is available for risk, supervision, and profit,

assuming that capital is borrowed at 6 per cent. There is no formula for splitting income among these three items; that is a matter for the business judgment of the individual. Christmas-tree growing is known to be rather risky as regards both production and marketing. It is something like the growing of rabbits, pecans, and mushrooms, in that large profit possibilities exist on paper which, for a good many reasons, may or may not be realized in practice.

The valuation procedure brings all facets of the problem into focus and provides a useful framework for their scrutiny separately and together. It should be regarded as a penetrating kind of problem analysis, and not as a series of dubious dollar assumptions tied together by compound interest. The latter is much too narrow a view. A broader purpose of valuation is to enable one to make the best assumptions possible at the time, to appraise their strengths and weaknesses, and then to use the results as a guide in getting the information necessary to give balanced direction to the work.

For example, determination of the income items in our illustrative problem reflects the end result of the entire marketing process and includes such considerations as wholesale and retail prices received by grade, size, and species of tree, transportation costs, jobbing and retail handling practices, general marketing risks, and consumer preferences. Information on all of these things is required to answer the simple question: How much can a producer get for his trees?

Similarly, estimation of the cost items covers the entire production process, and each figure represents the result of a series of operations. The cost of planting and of necessary replanting requires that the desirable number of trees per acre, the season and method of planting, the size and character of the stock, and the probable mortality be considered and decided upon. How much shaping is worth while and how can it best be done? Is the cost of shaping equal by years, as is rather arbitrarily assumed in our illustration, or does the work come to a peak in the fifth and sixth years? What are real spraying needs? What is the rental cost of suitable land, and what is a proper charge for capital costs? As can be seen, the virtue of the valuation analysis is that it requires that specific attention be given these matters and that some judgment be made of their importance and of the probable accuracy of the figures used.

The same general form of calculation may be used to estimate returns from applying different rotations and cultural practices and

from planting other species. Provided that the computations are consistent as to interest rate and methodology and are based on reasonably accurate cost and return data, the results are at least indicative of total profit possibilities. Even more important, they measure the relative financial desirability of various projects or alternatives with considerable validity. Similar calculations can also be made to investigate the growing of other forest crops, as for pulpwood or saw timber, or to evaluate a number of management possibilities in existing forest stands. The procedure is of wide application, even though the specific analysis required varies widely and necessitates some judgment and skill if it is to be applied effectively.

The underlying pattern of both the valuation examples presented here is one of an investment or of a series of investments made in expectation of a future return—an exceedingly common situation in forestry. Though I would again emphasize that everything in forestry cannot be measured or expressed in terms of dollars, financial aspects none the less bulk large. To the extent that they do, analyses of the sort illustrated here have utility in leading to sound decisions on the many questions of value that constantly confront the forest manager. They should be more widely applied.

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SOME COST ASPECTS OF PRUNING RED PINE

LA MONT G. ENGLE

ALMOST half of the more than one million acres of forest plantations in the Lake States region are devoted to red pine (*Pinus resinosa* Ait.). In the future this species will provide the greatest proportion of locally grown, pine saw timber. The rate of natural pruning is extremely slow, and it is apparent that if it is relied on most of the lumber obtained from red-pine plantations will be of low quality, even if rotations up to 120 years are followed. Thus, if an appreciable quantity of knot-free lumber is to reach the market, artificial pruning must be practiced.

The primary consideration in determining the feasibility of artificial pruning is the economic one. It is well known that clear wood can be produced through pruning, but there is a divergence of opinion on whether or not pruning investments pay dividends. Investigations of the real cost of obtaining clear wood under different financial and physical conditions are needed to estimate the economic limits of pruning. Techniques also have to be worked out with regard to the best time and the best methods of carrying on this work.

In the fall of 1950 the Lower Peninsula Forest Research Center began to explore the financial aspects of pruning red pine. Using handsaws and pole saws, the workers pruned from 20 to 100 trees to heights of 8.5 feet, 12.5 feet, and 17 feet on each of five plantations of different age. Data were obtained on actual pruning costs, and observations were made on methods of crop-tree selection and on pruning procedures.

Cost Considerations

Pruning costs fluctuated considerably because of differences in the size of the limbs, the number of whorls, the number of limbs per whorl, the condition of the limbs (dead or living), the kind and the condition of the tools, the terrain, the spacing of the trees, the weather, and the efficiency of the workers.

Presumably, pruning time is related directly to the surface area

cut, and therefore it varies with the square of the diameter of the branches; the variation becomes significant in branches larger than one inch in diameter. Branch diameters of plantation-grown red pine vary with the spacing, the age, and the quality of the site, spacing being one of the most important factors. The characteristics of the individual trees and the height at which the branches occur on the bole in relation to the total height at a given age also affect limb size. The largest branches are found near the base of the live crown, while the smallest branches are those nearest the ground and those nearest the top of the tree.

The time required for pruning dead limbs is much less than that needed for live limbs of the same diameter; as decay increases, the dead limbs are even more easily trimmed. Furthermore, dead limbs do not have the basal swelling characteristic of live limbs, so that a cut flush with the trunk can be made with a smaller scar.

No tests were made of different types of saws, but current opinion favors a curved saw at least 14 inches long, with from 6 to 8 points to the inch, as the most efficient tool. For small branches, long-handled clippers are faster, but they leave about a quarter-inch stub, which partially defeats the purpose of pruning. Either pole saws or ladders and handsaws can be employed in pruning the upper portions of the bole. The choice will depend on conditions in the stand and the preference of the men in charge. If pole saws are chosen, it is better to have two poles of different lengths for all work above 8 feet, rather than one 13-foot saw. A 7-foot pole saw can be effective in trimming the bole up to 13 feet, and then the 13-foot pole saw should be used for the remainder of the work. G. J. Meylan, of New York, has developed a 16-inch curved saw, with 8 points, which is mounted on a single-bitted ax handle. It has been described by Cook (2). This tool can prune up to a height of 9½ feet with about the same efficiency as the common handsaw, which can reach effectively only to about 7½ feet.

Time Required to Prune to Various Heights

The total time required to prune a tree to any given height varies considerably (Table I). The average total time to trim to 17 feet is usually from 9 to 10 minutes per tree if pruning is done in three operations, or from 1 to 2 minutes less if it is done in one operation. These results agree with those of Bramble and Schmidt (1), in Pennsylvania, who used ladders and handsaws. They found that

an average of 9.6 minutes per tree was necessary to prune to 17 feet in three operations, whereas 7.8 minutes was needed for such pruning in one operation.

Less total time is required to prune from 8.5 to 12.5 feet than from the ground to 8.5 feet (Table I) because of the fewer number of whorls to be cut in this section. However, the cost of clear bole per linear foot is higher in the 4-foot section (8.5 to 12.5 feet) because the 7-foot pole saw is not so efficient as the handsaw and the limbs here either are alive or have not been dead so long as the lower branches. The most time is needed to prune the section from 12.5 to 17 feet because of the low efficiency of the long-handled pole saw and because the branches in this upper section usually are larger and more likely to be alive. Bramble and Schmidt (1) found the same increase

TABLE I

TOTAL TIME REQUIRED TO PRUNE IN THREE OPERATIONS, PER TREE AND PER LINEAR FOOT

Height to which tree is pruned, in feet	*Normal range, in minutes*	
	Per tree	*Per linear foot*
Up to 8.5	3.0– 3.5	.35–.41
8.5–12.5	2.5– 3.0	.62–.75
12.5–17.0	3.5– 4.0	.78–.89
Up to 17.0 (one operation)	6.6–13.5	.53–.62

in cost per linear foot with increase in height of pruning when ladders were used instead of pole saws.

If the pruning is to be carried on in two or three steps, it is best to trim to a height of at least 8.5 feet in the first operation, for if, through some unforeseen circumstance, no further work is done, at least one clear 8-foot log can be obtained. The Meylan saw or a short pole saw should be used instead of a handsaw for this first operation. If the tree is to be pruned to a height of 17 feet in one operation, there is no need to prune to any specific height with each saw.

The expense of pruning increases rapidly with height. It costs more than twice as much per linear foot to prune the tree between 12.5 feet and 17 feet than it does to prune up to 8.5 feet. When only a small amount of money is available, it might be more profitable to confine pruning to the first 12-foot log on a considerable number of the trees rather than to prune fewer trees to a full log length of 16 feet.

Crop-Tree Selection

The investment required is usually so large that only the pruning of carefully chosen crop trees may be economically feasible. If final-crop trees are cleared to 17 feet, with a harvest diameter of 18 inches assumed, about 100 trees per acre should be treated. Even if a few unpruned trees are still standing for the final cut, no money has been wasted. When from 200 to 300 trees per acre are pruned, it must be recognized that most of them will be cut as small sawlogs or cabin logs before an appreciable band of clear wood has been laid on.

The selection of crop trees in plantations with high survival rates and good-quality growth may be made on a somewhat mechanical basis to reduce the cost and to obtain a regular spacing in the plantation. There is no need to have crop trees in every row. In plantations spaced at 6 × 6 feet or 8 × 8 feet, every third row might be skipped. Within the two rows in which crop trees are chosen, a fixed minimum distance may be left between treated trees in order to have a given number of well-spaced, pruned crop trees per acre. For example, in a plantation spaced at 6 × 6 feet the minimum distance between pruned trees might be set at 12 feet. This would mean a *maximum* of 200 such trees per acre. An average spacing of 20 feet would provide about 110 crop trees per acre. By leaving every third row without any pruned trees, provision is made to permit a row thinning, if this should prove desirable.

Successful selection of crop trees becomes progressively easier in older plantations. In plantations having trees under 15 feet tall, branching is not heavy and the visibility necessary for choosing the best trees for pruning is not yet impeded. However, with trees of this height and age the chances of losing the selected ones through injury, disease, or competition are increased. In plantations spaced at 6 × 6 feet and with trees 15 to 20 feet tall it is sometimes difficult to choose crop trees because of poor visibility and the difficulty of moving through the interlaced green branches. In plantations with trees over 25 feet tall the lower branches are usually dead, visibility is improved, and the chances for the successful selection of final-crop trees are fairly good.

If at all possible, crop-tree selection should be combined with pruning to avoid the extra cost involved in marking the crop trees separately. Carefully trained workers should be able to choose the trees for pruning without relying on earlier markings.

Discussion of Pruning Methods

The method of pruning requiring the least amount of supervisory and administrative time is that in which the entire job is done in one operation, after competition has caused the death of the branches up to at least 10 feet on the boles and after the trees are at least from 30 to 35 feet tall. By this time the trees will be clearly differentiated into crown and vigor classes. Crop trees can then be easily selected and pruning can be completed up to 17 feet without retarding their growth. About 100 trees per acre should be pruned to a height of 17 feet. This should not take over 2 man-days per acre. The most skilled members of the crews could select crop trees and prune to about 7 feet with a handsaw. With the crop trees thus identified, the others could then finish the job with pole saws or ladders and handsaws. This method would be satisfactory in plantations having 6 × 8 foot spacing or in more closely spaced ones. The limbs of trees at such spacings ordinarily do not grow very large before they die, and the cost would probably be less than that of early pruning. The main disadvantage of the one-operation method is that the knotty core is larger than if pruning is done in three separate operations.

If intensive pruning is done, as is sometimes feasible in the most accessible plantations on the better sites, from 8 to 9 feet of clear wood can be obtained on trees when they are about 3 inches d.b.h. As many as from 200 to 250 trees per acre might be trimmed in the first operation. Then, in later operations, only the best 100 trees would be pruned to a full log length. The trees cleared up to only 8 feet would be harvested in thinnings when they were from 10 to 15 inches d.b.h. The final cut would obtain clear 16-foot logs.

In plantations with spacings as large as 8 × 8 feet or 10 × 10 feet, the diameters of both boles and limbs grow more rapidly, and the lower branches die at a much slower rate, than in the closer spacings. By the time the trees are 35 feet tall, they usually have larger diameters than trees set nearer together. Here early pruning is essential if a knotty core of reasonably small size is to be achieved. At least three separate operations are required. Pruning of maximum severity should be practiced, so that the limbs may be cut while they are small. It is not definitely known what intensity of pruning retards growth significantly; however, it is safe to prune up to 50 per cent of the total height in young trees. Pruning to 8 feet would then be

done when the trees were about 15 feet in height. Successive prunings to 13 and 17 feet would be made as soon as the trees were large enough, probably when they were about 25 to 35 feet tall.

The economic feasibility of pruning depends not only on the initial cost, but also on the expected returns, which are contingent on the value differential between clear wood and knotty wood. The *rate* of return involves the time factor. In attempting to estimate the feasibility of pruning, almost any result can be obtained by assuming different costs, value differentials, interest rates, growth rates, and rotation ages. The interest rate selected can alone be made to show that pruning does—or does not—pay. If a low interest rate or none at all is used in figuring (e.g., when the cost of pruning is charged to current operating expenses), pruning would certainly seem to be profitable on almost all sites, so long as there was even a small differential between clear and knotty lumber. A high interest rate would make pruning worth while only on the best sites, over a short rotation. It is difficult to predict under what conditions one should or should not prune. The advisability of doing so depends entirely on the margin of profit that is required and on the individual conditions in each situation.

Summary

In 1950 a study of the financial aspects of pruning red pine was initiated in Michigan. Pruning up to 17 feet in three operations required, on the average, from 9 to 10 minutes per tree. Pruning in one operation required from 1 to 2 minutes less per tree. The cost of pruning the 4½ feet of bole extending from 12.5 feet to 17 feet was twice as much per linear foot as the cost of pruning up to 8.5 feet.

If trees are to be grown to a maximum size of 18 inches d.b.h., only about 100 crop trees per acre need be pruned. About 2 man-days per acre would be required to trim this number of crop trees.

The profitability of pruning varies with different growth rates, rotation ages, interest rates, pruning costs, and the value differentials between clear and knotty wood, so that no general recommendations can be made in regard to it, except that with low interest rates and good growth rates pruning certainly would appear to be worth while.

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SOME EFFECTS OF STAND DENSITY ON THE HEIGHT GROWTH OF RED PINE ON POOR SITES IN NORTHERN LOWER MICHIGAN

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Introduction

A GENERAL conclusion to be drawn from a careful review of the literature of coniferous silviculture is that stand density has little influence on the height growth of most pine species. This concept has been attested to by Deen (5), Gevorkiantz and Hosley (7), and Hawley (8), who worked primarily with eastern white pine (*Pinus strobus* L.) in the eastern United States. A slash-pine (*P. caribaea* Morelet) spacing experiment was reported by Mann and Whitaker (9) to show no measurable differences in total height with variations in stand density. Rudolf (11) found this to be true also of young jack pine (*P. banksiana* Lamb.) in plantings with a wide range of spacing intervals in lower Michigan. I (10) came to the same conclusions after measuring stands in a twenty-five-year-old jack-pine spacing test in lower Michigan.

Similar relations between stand density and height growth have been reported for red pine (*Pinus resinosa* Ait.). A forty-year-old Wisconsin plantation of red pine which did not respond in height growth after thinning has been described by Wilson (13). Schantz-Hansen (12) also found that thinning an overdense, young red-pine stand in Minnesota did not improve height growth. Bickerstaff (3) showed that thinning had no effect upon the height growth of red pine in eastern Canada, and Bramble, Cope, and Chisman (4), working with a twenty-five-year-old red-pine spacing study in Pennsylvania, discovered no significant differences in the average height of the dominant trees.

A few instances are recorded, however, in which stand density has definitely affected height growth. Adams and Chapman (1) have described a plantation-spacing study of pines—jack, red, eastern-white, pitch (*Pinus rigida* Mill.), and Scotch (*P. sylvestris* L.)—established

on a loamy-sand site in Vermont in which height growth was retarded by close spacings. Differences in the average height of dominants were not so pronounced for jack, pitch, and Scotch pines, species more adapted to poorer sites, as they were for red and eastern white pines, species more exacting in site requirements. Engle and Smith (6) recently reported that in lower Michigan height growth of both an overstocked natural red-pine stand and a forty-year-old plantation with a 5 × 5 foot spacing was improved by moderate thinning. Baker (2) reported an instance in which open-grown ponderosa pines (*P. ponderosa* Dougl.) in northern California were taller than those of the same age growing more closely spaced on the same site.

The present paper describes an early red-pine plantation in northern lower Michigan in which stand density has apparently affected height growth. The trees were originally planted at spacings of about 4 × 4, 6 × 6, 6 × 8, and 8 × 9 feet. Within this range of spacings, height growth after thirty-five years has been adversely affected by increasing stand density.

The Experiment

In the spring of 1918 a series of red-pine planting tests were established by the staff of the Huron National Forest to determine some of the effects of spacing interval on the growth and development of this species. The test area is located in the N. ½ Sec. 11, T. 23 N., R. 7 E., Iosco County, Michigan, near Lumberman's Monument. The area is known locally as the "Buck Creek plantations." The soil is classified as Grayling sand and the site is very poor for red pine.

Locally grown 2–0 seedling stock from Minnesota seed was slit-planted in furrows at spacings of approximately 4 × 4, 6 × 6, 6 × 8, and 8 × 9 feet. These spacings give about 2,720, 1,210, 910, and 605 stems per acre, respectively. Initial failures were light, but fail spots were replanted for two years after establishment of the plantation in order to maintain the original spacing intervals.

Since these planting tests, although experimental in nature, were administrative trials, there were no replications of them on other sites. However, the various spacings were made under fairly uniform conditions. Each planting block was established on the same type of soil, on fairly level topography, by the same planting procedure, and from the same lot of planting stock. There may be variables present other than the initial spacing interval, but they are not apparent.

A study with a better experimental design would be desirable in

order to draw final conclusions, yet these red-pine spacing tests are, according to my knowledge, the only ones of similar age or development in Michigan, except for one test in the Kellogg Forest in southern Michigan on a good pine site. A well-designed spacing study of red pine initiated by the Lake States Forest Experiment Station on the Huron National Forest was destroyed by fire in 1946, before any tangible results were evident. Other existing blocks of red pine are not feasible for a study of this type since they include some natural cover in addition to the planted trees.

Staff members of the Lower Peninsula Forest Research Center examined and measured the stand at Buck Creek thirty-five years

TABLE I

RED-PINE GROWTH, 1918–52

Original spacing, in feet	No. of stems per acre		D.B.H. of average tree, in inches	Basal area, in sq. ft.	Average total height, in feet		Volume per acre*	
	1918	1952			Dominants	All trees	Cu. ft.	Cords
4 × 4	2,722	2,319	3.2	132.0	25.4	21.7	1,300	2.1
6 × 6	1,210	1,114	4.5	124.5	27.8	24.7	1,390	9.8
6 × 8	910	868	5.1	121.9	29.8	26.4	1,440	14.1
8 × 9	605	588	5.9	111.1	31.5	27.5	1,410	15.6

* Rough cubic-foot volume of main stems of all trees in stand, and merchantable pulpwood volume of all trees 3.6 inches d.b.h. to a 3-inch top d.i.b.

after it had been planted. The measurements were taken in a fixed pattern, starting at points chosen at random within each spacing. Total height was plotted over diameter at breast height in the field. After it was apparent that enough height measurements had been taken to fit a good curve, only diameters were recorded. The data are based on approximately 100, 500, 200, and 75 trees for the 4 × 4, 6 × 6, 6 × 8, and 8 × 9 foot spacings, respectively. This variation in the number of sample trees was due to the different sizes of the areas occupied by the various spacings.

RESULTS AFTER THIRTY-FIVE YEARS OF GROWTH

After thirty-five years' growth at the four spacings, the effect of stand density upon the total height of the average dominant tree in each plot is most striking. The dominant trees now average 25.4,

27.8, 29.8, and 31.5 feet in height for the 4 × 4, 6 × 6, 6 × 8, and 8 × 9 foot spacings, respectively (Table I).

TABLE II

AVERAGE HEIGHT BY DIAMETER CLASSES OF RED PINE AT VARIOUS SPACINGS

D.B.H. class, in inches	Average height of trees, in feet			
	4 × 4 ft. plot	6 × 6 ft. plot	6 × 8 ft. plot	8 × 9 ft. plot
2	17	16	..	..
3	21	21	20	..
4	24	24	23	23
5	26	26	26	25
6	..	28	28	27
7	..	..	31	30
8	..	..	..	33

TABLE III

STEMS PER ACRE BY DIAMETER CLASSES IN RED-PINE STANDS AT VARIOUS SPACINGS, 1952

D.B.H. class, in inches	No. of living trees per acre			
	4 × 4 ft. plot	6 × 6 ft. plot	6 × 8 ft. plot	8 × 9 ft. plot
1	162	...	...	...
2	504	48	42	...
3	806	64	85	34
4	706	461	190	50
5	141	430	225	101
6	...	111	257	268
7	...	...	58	101
8	...	...	11	34
Total	2,319	1,114	868	588

The form class of the trees in the four plots of different spacings is practically the same regardless of spacing: trees of the same diameter tend to be approximately the same height even though stand density varies (Table II).

The diameter of the average tree in each plot increases with the spacing interval between trees. The average d.b.h. is 3.2, 4.5, 5.1, and 5.9 inches for the four spacing intervals (Table I). A stand table (Table III) which tabulates the distribution of stems per acre by d.b.h. classes for the various spacings shows that less than 10 per cent of the trees spaced 4 × 4 feet are over 4 inches d.b.h., in comparison with over 85 per cent of those spaced 8 × 9 feet and nearly 65 per cent of those spaced 6 × 8 feet.

The plots with 6 × 8 and 8 × 9 foot spacing have only a slight difference in merchantable pulpwood volume per acre (14.1 and 15.6 cords, respectively). However, the plots spaced at 6 × 6 and 4 × 4 feet have only 9.8 cords and 2.1 cords per acre, respectively, which is a sizable difference in merchantable volume after thirty-five years (Table I). Total cubic-foot volume per acre is about the same regardless of spacing, except for the closest spacing, which has slightly less volume per acre. Many of the trees at the closer spacings, especially in the 4 × 4 foot plot, are growing very slowly, while most of those spaced 6 × 8 and 8 × 9 feet are still growing as well as can be expected considering the quality of the site.

Both the average branch size and the live-crown ratio increase with the spacing interval. All of the spacings have practically excluded competition from other species and from brush. Dominance has been expressed even in the closest spacing, but by fewer trees than in the wider spacings.

Discussion of Results

The first question which comes to mind in this report is why stand density has had such an apparently limiting effect upon the height growth of the dominant and codominant trees in the Buck Creek plantations—an effect that is contrary to what has appeared in most studies and observations made elsewhere. An examination of the literature reveals that the majority of the experiments related to the influence of stand density on the height growth of red pine were made on sites fairly productive for that species. The Buck Creek plantations in northern lower Michigan are on Grayling sand, however, one of the poorest pine soils in the region. In those previous studies in which stand density is reported to have had a significant effect on height growth, the red pine was likewise growing on sites that were more adapted to other species (1, 6). In the Buck Creek area, within a relatively narrow range of densities, competition for the limited soil

moisture available apparently became so intense that height growth as well as diameter growth was affected. Since the most closely spaced plantings at Buck Creek were established at regular intervals that were less close than spacings in many natural stands, and since red pine does not tend to express dominance so well as some other coniferous species, such as eastern white pine, natural mortality at the 4 × 4 foot spacing has lagged far behind the amount which would be expected in natural stands. This study furnishes a striking example of what happens when competition beneath the soil surface affects growth before competition for crown growing space becomes acute.

The trees spaced at 4 × 4 and 6 × 6 feet are badly in need of a thinning; however, a commercial cut cannot be made in the denser plot and is hardly practicable even in the 6 × 6 foot plot. The plot with the 6 × 8 foot spacing was thinned in the spring of 1952 by a commercial cut, as part of a thinning study. The one spaced 8 × 9 feet has not needed any silvicultural treatment to date and probably will not be thinned for at least five years.

Summary

In this paper a reforestation test in northern lower Michigan is reported in which red-pine height growth has been retarded by close spacing on a poor site. After thirty-five years the dominant red-pine trees in a plantation spaced at 4 × 4, 6 × 6, 6 × 8, and 8 × 9 feet averaged 25.4, 27.8, 29.8, and 31.5 feet in total height, respectively. In addition to the fact that height growth was less as spacing between trees decreased, it is noted that the merchantable volume of pulpwood in cords increased as the spacing interval increased.

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